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MOVEMENT A CLUE TO BRAIN ACTION

ONE WAY TO STUDY A CHILD

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by
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PREFACE

The object of this book is to induce young folk in contact with children to observe and describe them in the way first outlined by the late Francis Warner, M.D., F.R.C.P., F.R.C.S., Senior Physician to the London Hospital.

He applied to the observation of 100,000 children, in many schools, principles which he had developed during a long experience of children.[1] He shewed, that from such observation, scientific inferences may be deduced as to the modes of brain action. The power to make such observations and inferences is needed at all stages by those planning the training of a particular child or group of children.

In early contacts with Dr. Warner at the beginning of my teaching career, I was much attracted by his scientific method in the observation of children, but mistakenly, I then believed that it was mainly applicable to mental defectives. What I absorbed from his teaching widened and made more objective my own outlook, but I did not seriously attempt to observe, describe, and draw inferences, in the way

[1] See Scientific Study of the Mental and Physical Conditions of Childhood: based upon the Examination of one hundred thousand Children in *Cyclopœdia of the Diseases of Children*, Keating, Vol. V, 1899. For list of Articles and Reports by Dr. Warner see *The Nervous System of the Child*, pp. 217-22.

outlined in Dr. Warner's two books both published by Macmillan: *The Study of Children*, 1897, 1902, '04, '05, '07, '10, now out of print, and *The Nervous System of the Child*, 1900.

Probably I was unconsciously glad to feel excused from the discipline involved in such careful study of my children! Private teaching, lecture work in training college and polytechnic, science teaching throughout a large L.C.C. Elementary School, together with visits to every sort of experimental school, have since those days, brought me in contact with many varieties of educational theory and practice.

Then a few years back, after Dr. Warner died, I had the chance of reading through his unpublished MSS. and was struck by the way in which his early thoughts and researches seemed to have foreshadowed many recent ideas and discoveries.

I saw connections with the researches of such widely different workers as the late Prof. Pavlov, Dr. J. B. Watson, Prof. Köhler, Prof. E. Holt, Prof. Arnold Gesell, Dr. Charlotte Bühler, Prof. E. C. Thorndike, and F. M. Alexander, Esq.

I am deeply grateful to Profs. Holt and Gesell for the extraordinarily kindly way in which they answered queries which I ventured to put to them when I was hoping to write a more ambitious book than this.

I finally came to the conclusion that before anyone could write *that* book, much more observation and description of children on the scientific lines indicated by Dr. Warner must be carried out, and that by younger folk than myself. This book, therefore, only aims at giving students, teachers, and parents enough understanding of the principles and method to show them the desirability of such observation and description of children.

Miss Leta Opie, B.Sc., Lecturer in Education, Portsmouth Training College, very kindly told me which parts of *The Study of Children* seemed to her most valuable from a student's point of view. It is mainly those which are incorporated here. Dr. Warner advocated much that has since been undertaken by the School Medical Services, so that many points are omitted here which he dealt with in *The Study of Children.* One such is the observation and description of 'Developmental Defects'. Although these have much bearing on the question of the educability of any child, they seem to me to belong to the province of the School Medical Officer rather than to that of student or teacher.

Since observation, unless accompanied by careful written description, will not produce valuable inferences, the kernel of this book is Chapter V with its 'Schedules for Report on a School Child'. These are slightly adapted from those in *The Study of Children* and *The Nervous System of the Child.*

Chapters I and II give, in the light of modern knowledge, some of the physiological reasons for the belief that a careful study of a child's movements and postures reveals the mode of its brain action. Examples from teaching practice suggest ways in which this knowledge of the mode of brain action is used in school to ensure the best training.

Quotations, kindly permitted by authors and publishers, link Dr. Warner's work with that of great modern observers, e.g. Charlotte Bühler, E. C. Thorndike, Edwin Holt.

Chapters III and IV are mainly extracted from *The Study of Children*, giving those movements and postures which can be most profitably observed and described, as indicative of modes of brain action.

Chapter V shows how observations may be recorded in report form. After consideration of such a written summary the teacher can then make out schemes for dealing with the child's needs.

Chapter VI gives certain exercises which Dr. Warner, and the writer, following and expanding his suggestions, have found useful in cases where observation has indicated that the exercises should be tried as part of the educational plan.

The parent, the doctor, the psychologist, are all studying the child. How does this particular way of looking at children differ from those of other observers?

The parent, observing mainly with an eye to the present and future happiness of the child, is concerned with all-round development, rarely can he be scientific or analytic in method, he has little chance to compare his own child with others.

The doctor is concerned with physical health and usually alas (except at the Pioneer Health Centre, Peckham!) only gets his chance of observation when disease has already begun. He regards movements and postures mainly as indicative of orthopædic and muscular conditions. He is not primarily concerned with them as signs of the way in which the brain is functioning.

The psychologist is mainly concerned with certain emotional or mental 'states of consciousness'. If he observes movements and postures at all in any detail he considers them in relation to such a 'state of consciousness'.

Again too, as in the case of doctors, most of the 'observers' at psychological clinics have been mainly dealing with abnormal and maladjusted children.[1]

All these ways of study are needed. But for the practical teacher, observation, description, and carefully guarded inference of mode of brain action on the lines suggested by Dr. Warner should precede, and form a basis for, further study of the child.

We know something of the nervous mechanism through which human personality emerges, but that mechanism itself cannot explain the whole process and this book deals with but one minute fragment of it. Still a partial and particular view is none the less true and reliable because it is partial, as long as it is not mistaken for a comprehensive explanation of the whole. Some readers may find the earlier physiological chapters difficult and wonder if such an approach is necessary. Yet no engineer attempts to put together a delicate machine unless he knows something about its parts. Parents and teachers are engineers helping to put together that very intricate machine, the child's nervous system. The tool they use is any stimulus passing to the child's sense organs from their own expression, gesture, voice, whether or no they are aware of the effect they are unceasingly thus producing. Such a stimulus will leave a definite trace in the child's nervous system. The early chapters explain in part how this happens. They are very inadequate, for we really need that some great neurologist should turn to the consideration of the work of parents and teachers and give them some account of the way his specialized modern knowledge bears on their problems of the emergence of mind. Meanwhile, these confessedly inadequate chapters may help some to see the need to observe, analyse and describe the physical indications (given by movements and postures) of brain activities and states in the normal child.

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[1] In this connection it is satisfactory to note that The Parents Association Institute in S. Kensington, Director Dr. C. Bühler, has as an object 'Child guidance in relation to the *normal* child'.

In his preface to *The Study of Children* (p. 6), Dr. Warner says: 'In the scientific (physical) study of children in their modes of brain action and bodily conditions, we should describe what we see, and employ no terms implying results of consciousness and states of feeling. . . . The study of such observations shows many new relations among growth, movement, and mental power. The principles used in biological study and natural history are here applied to child study.'

In such a method the stress is on the fact that visible movements and postures are reliable signs of modes of *brain* action. They are physical signs of physical action, which give clues as to how the brain may be trained in the best modes of such action. Where there has been such careful scientific observation and description of individual children on these objective lines the student has had a sound preparation for psychological study dealing with less tangible mental and emotional states of 'consciousness'.

H. F. C.

October 1936.

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CHAPTER I

MAINLY PHYSIOLOGICAL

Introductory

'A cool kitchen is used for a gas range.'

Teachers know that type of answer to such a question as: 'What are the advantages of a gas cooker over a coal range?' The child understood the question and knew the necessary facts for an answer, but 'cool kitchen', evoked at once by the question, seized the motor path from brain to writing muscles, without sufficient pause to allow the brain connections to be made for an orderly answer. Such a brain has been badly trained. Contrast the remark of a two year old who pulled at the hairs on his father's wrist, and, when told that it hurt, said, in great surprise: 'But it didn't hurt grandpa!'

The two year old brain was functioning quite normally only it was lacking in experience.

Movements and postures are often paralleled by the mental acts of a child. The child who wrote the first answer would probably betray lack of brain training in movements and postures as well as in mental performances. If the former could be made normal for the child's age then the mental processes would likewise be found to have improved.

Some reasons for the belief that improvement in movement may mean corresponding improvement in mental process

1. The Central Nervous System is essentially a network of neurones (nerve cells with their processes) subserving both movement and mental activities, therefore one would expect that any improvement in the functioning of these neurones for movement would also mean improvement in their mental functioning. Faulty movement or posture is not just a symptom like a rash, which may disappear while the disease is still present, for permanent improvement of movement or posture indicates fundamental improvement in the functioning of the neuronic network.

2. We know that doctors in diagnosing and treating diseases of the Central Nervous System have long noted abnormal movements and postures as guides to the nature of the disease. So we expect that lesser abnormalities will indicate to the observant eye of the teacher—not disease among the neurones—but such failure in their functioning as may be remedied by training.

3. Mental development follows development in co-ordinated movement. The belief, that to improve movement and posture means to increase capacity for mental work, is greatly strengthened too by the fact that in the child mental development follows every achievement in muscular automatization, e.g. the automatic co-ordination of movements acquired when a child has learned to walk, is succeeded by increased understanding and use of words, a great step in mental development.

The physiological mechanism subserving movement and mental activity

Before, in the following chapters, we learn how to study movements and postures as clues to brain or neuronic functioning, we must first recall something of the physiological mechanism underlying alike co-ordinated movement and orderly thought.

The main factors involved in any movement are:
A Stimulus, stimulating
A Sense Organ, in eye, ear, skin or muscle. This results in
Nerve Impulses passing along
Afferent Nerve Fibres from the sense organ to
Nerve Cells situated near, but not within, the
Spinal Cord, when the sense organ is *in the skin or in a muscle*. Thence the nerve impulses pass across a varying number of
Synapses to other
Nerve Cells in the
Spinal Cord and thence via still other nerve cells to
Nerve Cells in the
Brain.

If the sense organ stimulated is in the *eye*, *ear*, *tongue*, *nose*, *throat*, practically anywhere in the head, the nerve impulses pass along nerve fibres direct to the brain.

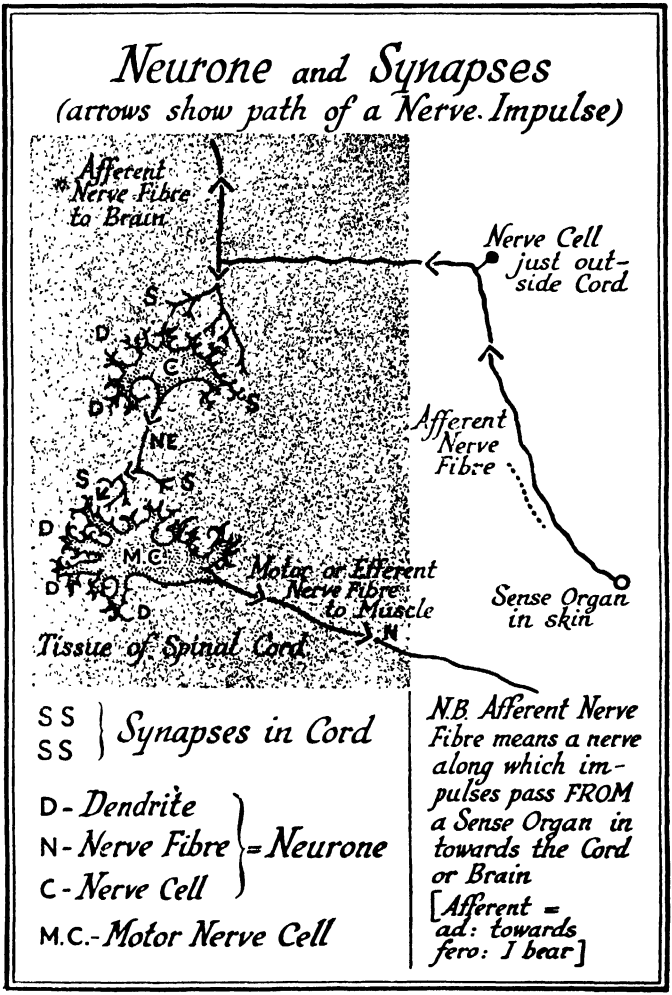
A Neurone, is a nerve cell with a number of finely branching processes the *Dendrites* and one usually much longer process the *Nerve Fibre* (Axon) which breaks up into fine branches at the end remote from the cell, and these come into close contact with the dendrites of other neurones at the *Synapses.*

Synapses, are the places where the branching ends of one nerve fibre (or axon) come into microscopically close contact, but not into actual union with the dendrites of another nerve cell. A nerve impulse will use a chain of neurones, varying in number and therefore in the number of synapses crossed, in passing from sense organ to brain. The central nervous system consists essentially of some 13,500 millions of neurones with their synapses. Stimuli must be of a certain strength and occur under certain time conditions before the microscopic gaps between neurones can become less, allowing nerve impulses to pass from neurone to neurone, (see pp. 46, 50, 83).

From nerve cells, either in the cord or in the brain, the nerve impulses continue on across a varying number of synapses till certain cells in the
Brain Cortex are reached. Then
Sensation is experienced, how caused we have no idea. This may be a sensation of heat, cold, touch, strain, pain, etc., if the sense organ stimulated was in the skin or in muscle. It may be a sensation of light or sound if the sense organ was in the eye or the ear. The nerve impulses pass on to other neurones in the brain across many synapses till at length they reach the *Pyramidal Cells* in *Cortex* and proceed from the brain by their axons, very long nerve fibres passing down the spinal cord to special
Motor (or Efferent) Neurones, and out of the cord by their
Motor Nerve Fibres to
Muscle Fibres.

Some of these muscle fibres are thereby caused to contract, others to relax and a movement occurs.

N.B. The reader is now advised to return to the



N.B. Afferent Nerve Fibre means a nerve along which impulses pass FROM a Sense Organ in towards the Cord or Brain [Afferent = ad: towards fero: I bear]

DIAGRAM I (*not drawn to scale*)

original Stimulus and trace out again the passage of the nerve impulse!

Every movement originated by some stimulus

There are many movements which appear to us to originate in some idea or thought, probably if we could know all the previous history, such movements could be traced back to a preceding stimulus which caused nerve impulses to reach the cortex of the brain, but of which the resultant expression in movement was delayed.

We must now consider in more detail the chain which we have just traced from the stimulus to the resulting sensation and movement.

What can constitute a stimulus?

Practically any change in the environment may be a stimulus.

A hand passing near, in front of an eye, causes an involuntary wink, i.e. a change in the intensity of the light rays reaching the sense organs (retinae) of the eye, starts nerve impulses travelling by the optic nerve to nerve cells in the brain. Thence nerve impulses travel out, by other nerve fibres, to muscles which contract and cause the falling of the eyelids. Simultaneously these ingoing nerve impulses have caused changes in certain neurones whereby the 'sensation' of shadow was evoked, as the hand passed in front of the eye.

In both cases these impulses on their way to produce sensation and movement have crossed many synapses

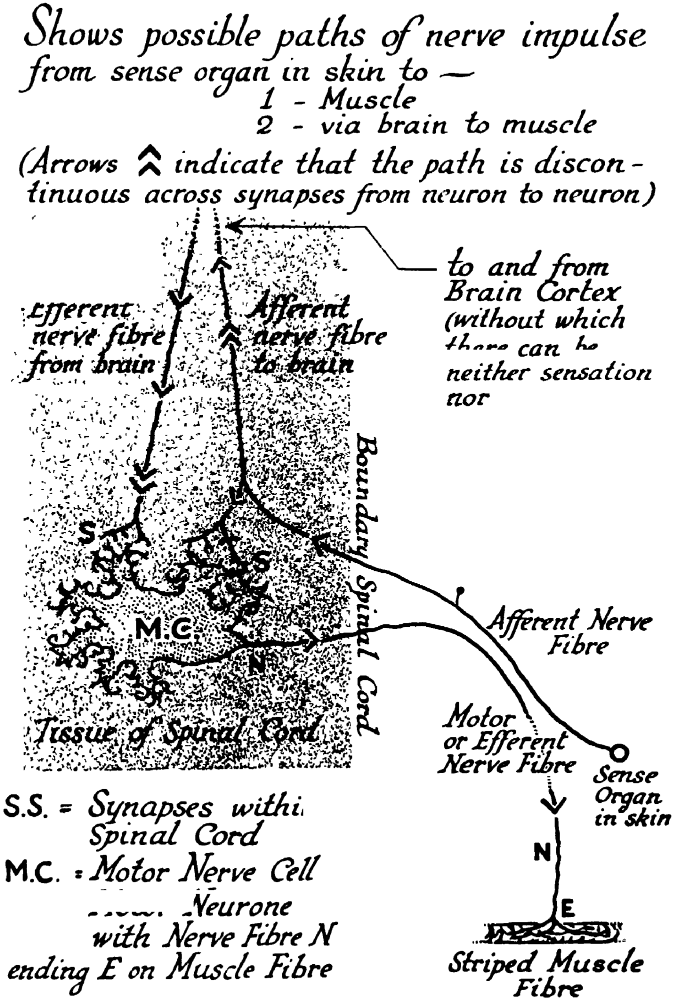

Shows possible paths of nerve impulse
from sense organ in skin to —
1 - Muscle
2 - via brain to muscle
(Arrows ⌃ indicate that the path is discontinuous across synapses from neuron to neuron)
Efferent nerve fibre from brain
Afferent nerve fibre to brain
to and from Brain Cortex (without which there can be neither sensation nor
Boundary Spinal Cord
S
S
M.C
N
Tissue of Spinal Cord
Afferent Nerve Fibre
Motor or Efferent Nerve Fibre
Sense Organ in skin
N
E
Striped Muscle Fibre
S.S. = Synapses withi Spinal Cord
M.C. = Motor Nerve Cell
Neurone with Nerve Fibre N ending E on Muscle Fibre

DIAGRAM II *(not drawn to scale)*

where the branching end of one neurone meets the dendrites of other neurones.

What are nerve cells, nerve fibres, nerve impulses?

A nerve cell is a microscopic scrap of protoplasm or living substance which continues out into the dendrites and into a longer process, the nerve fibre (or axon). Such protoplasm, as in all other cells, breathes, feeds, excretes waste substances, but here, in nervous tissue, it has also been specialized to receive and conduct nerve impulses.

No matter which sense organ is stimulated the nerve impulses produced are always of the same nature. This appears to be some kind of minute electrical change passing from particle to particle of the protoplasm of the nerve fibre, but the protoplasm of the fibre returns to its original condition almost immediately after the passage of the nerve impulse. Someone has compared this process of conduction of a nerve impulse along a nerve fibre to the passage of a spark along a string, if one imagines the string reconstituted at once behind the spark. Nerve impulses travel at varying rates, thus those which result from painful stimuli are the slowest.

Co-ordinated movement and orderly thought depend on the happenings at synapses

At the synapse, the change (? chemical ? electrical) that occurs, differs, so that here the passage of nerve impulses may be facilitated or delayed. This depends on what impulses have previously crossed the synapses, and when. This delay or facilitation at synapses is of great importance both for the co-ordination of movement and later on for the development of orderly thought.

There are some 13,500 million neurones, forming a most intricate network in the spinal cord and the brain and it would be structurally possible for any nerve impulse to pass to any neurone and thence eventually to stimulate and cause contraction of any muscle.

Something like this does, in fact, happen in strychnine poisoning, for strychnine affects the synapses, so that impulses are allowed to spread freely in any direction, thus causing agonizing contractions of many muscles simultaneously, whenever any sense organ is stimulated by the slightest change in the environment.

Limitation of the power of nerve impulses to wander freely leads to better integration with a wider environment.

In the mature healthy brain and spinal cord however, such chaos as that due to strychnine poisoning is prevented, since nerve impulses pass more easily through certain synapses than through others. If an impulse has just passed across a certain synapse, impulses immediately following will usually find that synapse more open for their own passage than others. Further, nerve impulses can only pass across synapses in the one direction (from the nerve fibre [or axon] of one neurone to the dendrites and cell of another) i.e. always from the sensory side of a neurone out towards the motor side leading towards the muscles.

During the evolution of creatures with a Central Nervous System having a steadily increasing number of neurones and synapses, such limitations of the paths possible for nerve impulses to follow, together with facilitation and delay at synapses, have everywhere impressed order on what otherwise would have been chaotic, first in the processes of movement, later in the processes of thought. As an illustration of the results of such limitation compare the life of the jellyfish (with its non-synaptic nervous system) with the salmon. Why is the life of the salmon so much more adventurous? Surely because, in the salmon, nerve impulses can no longer wander out freely as in the nerve net of the jellyfish. They are compelled by the development of synapses to follow certain paths out to muscles and the resultant movements lead to the salmon's adventurous life, integrating with a very wide environment. Limitation *of freedom for individual nerve impulses has led to a better integration with a wider environment.* The individual human being in its evolution from the embryonic to the adult stage here, as in so many cases, repeats the history of the race.

So we may see orderly movement evolving, if we study movement in the unborn, in the new-born baby and in the small child. Let us start with the more familiar.

Spontaneous movements in the new-born

(See also chap. III, p. 115.)

Look at a well-nourished baby, say seven days old, lying naked on his nurse's lap. Spontaneous or random movements are seen in the limbs, and especially in fingers and toes; these do not occur in any definite series or in any particular order, are slower than movements in most adults, are uncontrolled by external stimulations, and so are not directly useful to the child as far as dealing with his surroundings is concerned, but they are infinitely useful to him as the raw material of his future co-ordinated movement and thought.

Any heavy or long clothes which limit the scope of this spontaneous activity and prevent its full development should be avoided. A pretty mouth and absence of adenoids are much to be desired, but it is equally important that the fingers be left free to move spontaneously. They should not be rigidly confined in order to prevent thumb or fist sucking.

It may be that internal stimuli, e.g. from digestive and assimilative processes, are the primary causes of these important random movements but it can be seen that at this stage they are in no sense directed by such stimuli.

Movements in an older baby

Contrast with this 'random' picture the series of movements made by an older child in front of whom an orange is placed. Head and eyes turn towards it, next, after a pause, his hand moves out to the orange, fingers close over it and it is seized. Former stimuli, due to colour, smell, and form of the orange have already led to limitation of the neuronic pathways which are open to Nerve Impulses thus started, so that they now all converge upon the motor neurones leading to such muscles as, by their contraction, produce the above-mentioned 'useful' movements. A definite pattern of neurones has been built up, through which the nerve impulses pass, to control each movement.

Spontaneous movements of the new-born indicate the immaturity of his neurones

The random or spontaneous movements of the new-born baby are indications of the immaturity of his neurones. The new-born child possesses his full complement of neurones, he has (1) the afferent neurones, making up the nerves which conduct impulses from the sense organs to the spinal cord, (2) the neurones which conduct up and down the spinal cord to and from the brain, and (3) the motor (efferent) neurones by which impulses pass from the spinal cord to muscles. (1, 2, and 3 make up the complete nervous arc.) But there are few synapses as yet trained to function between these various neurones, while neither the afferent nor the motor neurones have as yet developed the insulating sheaths, which later on prevent any spreading of impulses from neurone to neurone except through synapses. Few patterns of neurones have been built up (see pp. 57 and 59, chap. II). For these reasons there can be very little co-ordinated movement.

Aimless nature of movements explained

Any sense organ developed enough to function will, when stimulated, send impulses along the afferent neurones to their nerve endings in the spinal cord, there to spread fortuitously and to continue along those neurones of which the dendritic endings lie nearest. Thus it is largely accidental what muscles are brought into action. This explains the aimless character of the spontaneous movements of fingers, toes, etc., in a well-nourished infant during its short wakeful intervals. For fuller description of such movements see chap. III,

We must now briefly consider certain factors which before birth play their part in preparation for co-ordinate movement.

Movements in the unborn

A few weeks prior to birth we know that a stimulus such as a pressure on an eyeball may spread to almost any muscle producing perhaps a twitch of an arm or of a leg, though it may also cause movements of eye parts—such as would occur later on when certain synapses have been trained to act together. But there are, as yet, no established paths for the nerve impulses. The movements of the unborn infant, brought about by pressure from its environment or by internal stimuli, are random writhings.

Development of a co-ordinated from a random movement

Origin of grasp reflex illustrating part played by:

(a) spontaneous or random movements }
(b) external stimuli }
in bringing about co-ordinate movement

Even before birth a beginning has been made towards the development of certain co-ordinated movements and the steps in neurone training which bring about one of these—the Grasp Reflex[1]—may now be described: (Diagram III, p. 40).

If you touch the palm of a new-born baby with your finger his fingers close firmly over yours. Quite a number of muscle fibres have contracted or relaxed synchronously to produce this movement, telling us that in the prenatal life random movements have been transformed into co-ordinated movement through the arrival of an external stimulus at the appropriate moment. In the unborn child, internal stimulation—possibly digestive in origin—set up nerve impulses which passed out by motor nerves and caused 'random' contractions of various muscles. One of the resultant movements brought one of the unborn child's fingers against its own palm. At once sense organs (of touch) in the palm were stimulated and nerve impulses passed up the afferent nerves from the palm to the spinal cord. These afferent nerve fibres enter the spinal cord near the synapses of those motor nerves down which have just passed the impulses which caused the preliminary random muscular contraction (bringing finger against palm). Because of this recent passage of impulses these synapses are especially ready to let fresh impulses pass. Consequently the returning impulses from the stimulated 'touch' sense organ in the palm, find their outlet at once by the motor neurone to the already contracting muscles bending the finger. So the 'grasping' movement is reinforced. Further reinforcement occurs through stimuli arriving from muscle sense organs in the contracting muscles and in the joint of the bent finger. (For a diagram of muscle sense organs see chap. II, p. 101.)

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[1] See Professor Holt in *Animal Drive* for fuller details.

When skeletal muscles contract, the resulting pressures stimulate sense organs in these muscles. These sense organs are the endings of afferent nerves by which the impulses set up by the stimulating pressure are carried back to the spinal cord, entering it near the very motor neurones down which passed the impulses that caused the original contraction.

Explanation of diagram IV: Grasp Reflex B

In the unborn child random movements are occuring. The diagram suggests how a nerve impulse responsible for such a movement may have arrived by the nerve fibre N. at the synapse, So of a motor neurone. The impulse passes across the nerve cell M.C., down the motor nerve M.N. to its ending E. on a muscle fibre $M.F_1$. This fibre then contracts, along with many similar fibres so a finger is bent till it touches the palm. At once stimulation by pressure occurs of three or four different types of sense organs setting up nerve impulses in many nerve fibres. Three samples of such nerve fibres are shown: A1, A2, A3. A1 is an afferent nerve fibre coming from a sense organ in the finger joint (joint not shown). A2 is an afferent nerve fibre from a muscle sense organ M.S. which is wrapped round the contracting muscle fibre, $M\ F_2$.

When a muscle contracts, pressure starts nerve impulses in A1 and A2. These impulses pass up the nerve fibres to their nerve cells which lie near but not in the spinal cord at G1 and G2. The impulses pass on into the cord and set up many impulses there, some passing to the brain causing sensations of muscle tensions, (see chap. II, p. 101) others, either directly, or indirectly by way of intervening neurones, to M.C. Such passage to

Diagram illustrates arrival of nerve impulses by nerve fibre N at motor cell M.C. in Cord:

These impulses cause contraction of muscle fibre at E and consequent return of impulses to M.C.

from S = Muscle Sense Organ
T = Touch Sense Organ in palm
F = Sense Organ in finger joint

These impulses all cause fresh impulses to pass out from M.C. to E and reinforce contraction of muscles bending finger

GRASP REFLEX A

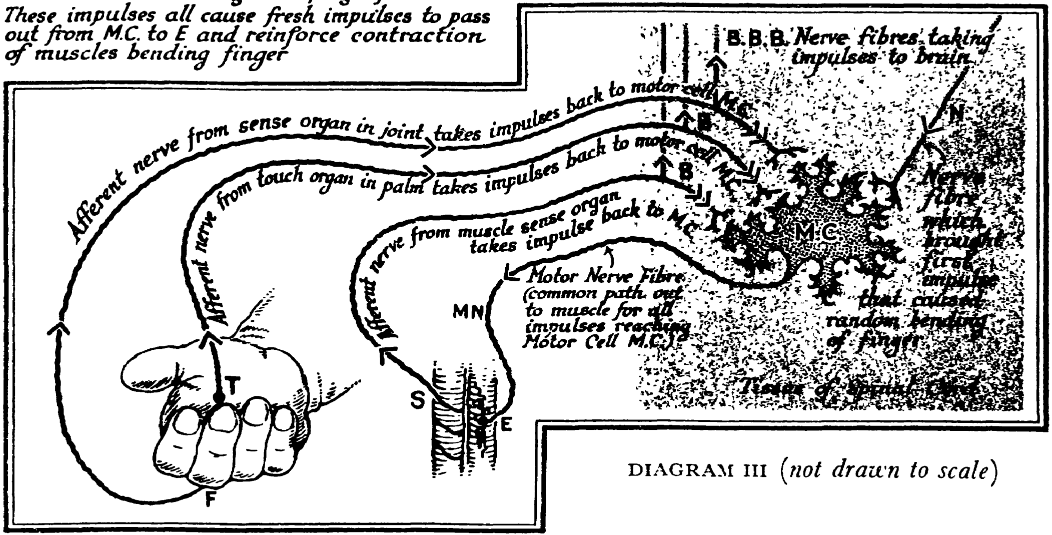
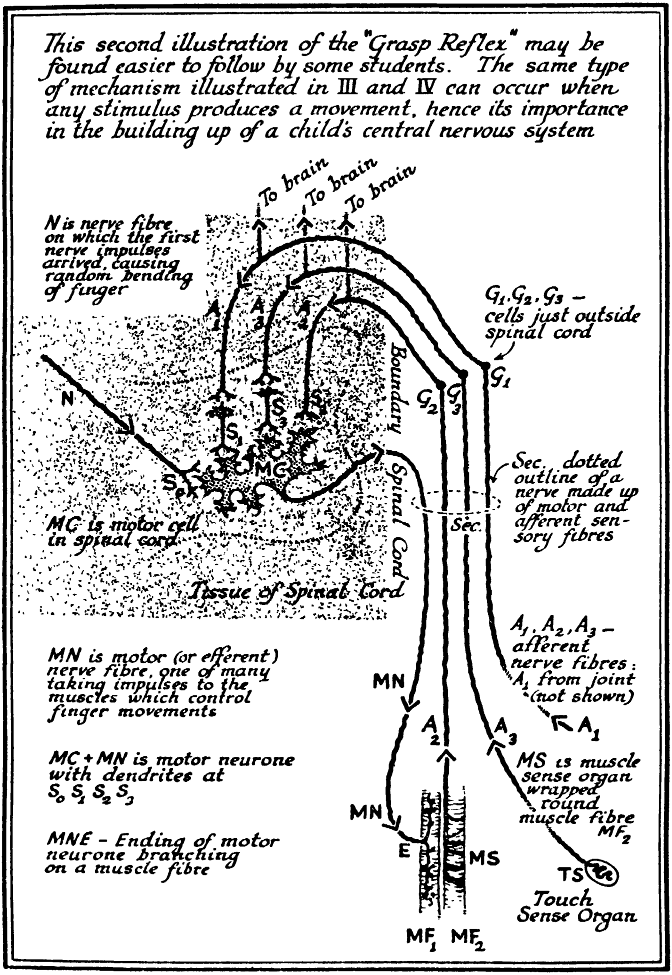

B.B.B. Nerve fibres taking impulses to brain
N
Afferent nerve from sense organ in joint takes impulses back to motor cell M.C.
Afferent nerve from touch organ in palm takes impulses back to motor cell M.C.
Afferent nerve from muscle sense organ takes impulse back to M.C.
B
B
M.C.
Nerve fibre which brought first impulse that caused random bending of finger
Motor Nerve Fibre (common path out to muscle for all impulses reaching Motor Cell M.C.)
MN
T
S
E
F
Tissue of Spinal Cord

DIAGRAM III (*not drawn to scale*)

GRASP REFLEX B



This second illustration of the "Grasp Reflex" may be found easier to follow by some students. The same type of mechanism illustrated in III and IV can occur when any stimulus produces a movement, hence its importance in the building up of a child's central nervous system

N is nerve fibre on which the first nerve impulses arrived, causing random bending of finger

G_1, G_2, G_3 – cells just outside spinal cord

Sec. dotted outline of a nerve made up of motor and afferent sensory fibres

MC is motor cell in spinal cord

A_1, A_2, A_3 – afferent nerve fibres: A_1 from joint (not shown)

MN is motor (or efferent) nerve fibre, one of many taking impulses to the muscles which control finger movements

MC + MN is motor neurone with dendrites at S_0 S_1 S_2 S_3

MNE – Ending of motor neurone branching on a muscle fibre

MS is muscle sense organ wrapped round muscle fibre MF_2

DIAGRAM IV (*not drawn to scale*)

M.C. is no longer random or by chance for the original impulse which caused the bending of the finger has only just passed across M.'s synapse, so this path is more open than the path to any other less recently stimulated neurone in this region. Further, the bent finger presses on the palm, and this stimulates 'touch' nerve endings here (see diagram V).

A3, diagram IV, represents the neuronic pathway from such a touch sense organ. Nerve impulses then travel up A3 to G3 which lies near G1 and G2, pass into the cord where they find the pathway across the synapse of M. more open than others, and so pass out down M.N.

So all these impulses, themselves set up by the original random movement, are guided into the same path out, to cause further contractions of the muscles which produced the original 'random' movement. The grasp reflex is thus reinforced. The fist will not however remain permanently closed, for another intricate mechanism causes relaxation of the contracted muscles. But, thereafter, any nerve impulses started by a similar stimulation of the touch sense organs in the palm, will, other things being equal, find outlet through the same synapses, to the muscle fibres which, by their co-ordinated movements, produce the 'Grasp Reflex'. So when you touch the new-born baby's palm his fingers close over yours with quite astounding power.

Chief factors in development of Co-ordinated from Random Movements:

This development of a co-ordinated 'useful' movement giving the infant a certain power of control over his environment, and, presumably, even a 'consciousness'—though very rudimentary—of such power, is seen to depend on two factors:

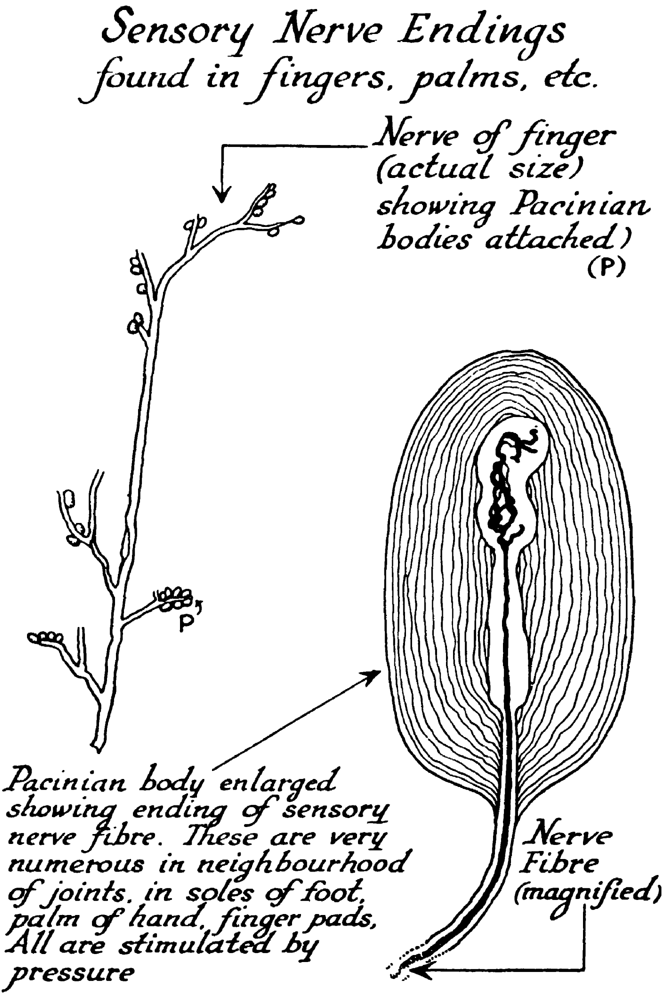

Sensory Nerve Endings
found in fingers, palms, etc.
Nerve of finger (actual size) showing Pacinian bodies attached)
(P)
P
Pacinian body enlarged showing ending of sensory nerve fibre. These are very numerous in neighbourhood of joints, in soles of foot, palm of hand, finger pads, All are stimulated by pressure
Nerve Fibre (magnified)

DIAGRAM V

1. *A preliminary random or spontaneous movement* caused, but not controlled by stimulation usually untraceable as to origin. Some investigators indeed consider that these spontaneous movements are caused by nerve impulses originating in the brain cells concerned.

2. *A definite external stimulus.* (Here, in the Grasp Reflex, the touch of the baby's own finger on its palm) arriving at a sense organ, just after, or simultaneously with, the random movement, so that the nerve impulses started by the external stimulus find their easiest pathways to be out to the muscles already contracting to produce the random movement. Similar stimuli thereafter will take the same pathway out, so that these movements become definitely controlled by certain changes in the child's environment and the muscles producing the movements are co-ordinated by that particular stimulus. In the Grasp Reflex this stimulus is pressure on the palm.

A simple pattern has been formed

Nerve impulses here have lost their freedom to spread widely throughout the Neuronic network, but the baby, by acquiring the power to grasp, has in a slight degree, acquired some control over his environment. A pattern has been formed. In this the afferent neurones, neurones in spinal cord and motor neurones connected up may be said to form a simple pattern. (For definition see p. 56) Random movements, stimuli coming in and leading to their co-ordination, that is the method by which neurones are 'trained' or built up into good patterns in the early days of life. (See also chap. II, p. 59, *et seq.* for spontaneous movement of a finger.)

Importance of muscle sense organs in training of neurones and building of patterns

The mechanism producing the grasp reflex has been described in this detail because it illustrates the extraordinarily important part played by our millions of muscle sense organs in neuronic learning. Similar processes occur during all movements and the mechanism should be kept in mind especially in reading chap. III, p. 129 on Eye-Movement and chap. I, pp. 50-55 as well as in the various examples involving Compound Cerebration, e.g. chap. II, pp. 66, 103, etc.

The actual condition of the neurones is clearly indicated by the type of movement in the unborn, new-born and slightly older child, and we may expect careful observation of movements at later stages in the child's life to give further clues as to how his neurones are functioning and what may be done by training to assist neuronic learning. The aim of such training is adequate stimulation, so that nerve impulses may establish synapses connecting neurones into patterns controlling first, useful movements and later on desirable mental activity.

A law[1] governing dendritic growth which partly explains how synapses become established

We are still far from understanding how synapses are actually established and neuronic patterns built up, but there is one fact concerning the growth of dendrites, which must largely influence co-ordination

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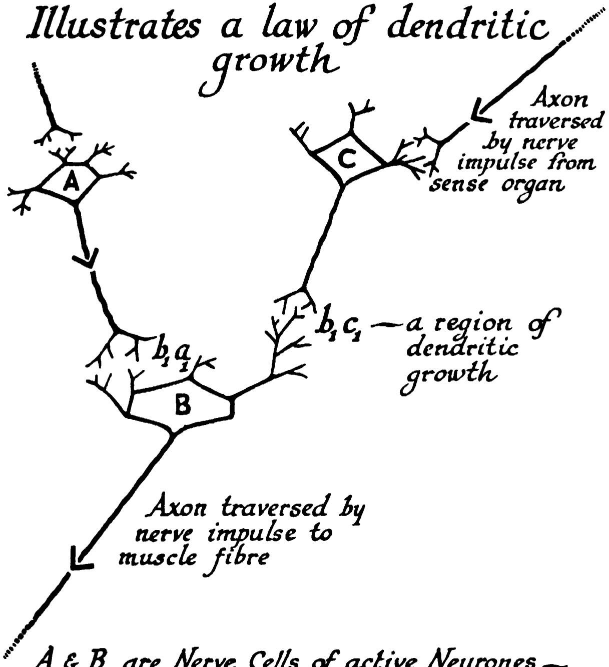
[1] Kapper's Law of Neurobiotaxes.

Illustrates a law of dendritic growth


Axon traversed by nerve impulse from sense organ
C
A
$b_1 c_1$ — a region of dendritic growth
$b_1 a_1$
B
Axon traversed by nerve impulse to muscle fibre

A & B are Nerve Cells of active Neurones — traversed by nerve impulses of so-called Spontaneous Origin. A nerve impulse from a sense organ, such as the ear, arrives simultaneously down the neurone whose nerve cell is C, and passes across synapse $b_1 c_1$ to B. It is known that there may then be growth of dendrites at $b_1 c_1$ and at $b_1 a_1$

This growth will lessen the gap at these points, and facilitate a similar course for future nerve impulses in this direction

DIAGRAM VI

through synapses and so must be an important factor in all neuronic learning. This is the fact that the dendrites of one neurone *grow towards* another *active* neurone, if nerve impulses are passing down *both* neurones, when certain of such nerve impulses are the result of the external stimulation of some sense organ. This growth of dendrites during the passage of nerve impulses in adjacent neurones is always in a direction counter to that of the impulse propagation, i.e. growth is from the motor side of the synapse, towards direction from which the impulses are arriving.

Continued dendritic growth implies continuous mental development

It is believed that power of growth in dendrites and the ends of nerve fibres (axons), as the result of adequate stimulation, is retained among the so-called association neurones of the brain until past middle age. These are the neurones especially concerned with our highest mental processes, so that this ability to grow and to form new synapses offers the possibility for the more numerous synaptic connections demanded by complicated mental processes.

Movements, as the earliest visible expression of pattern building indicate whether training is right

As teachers, we realize that stimuli, and stimuli occurring in a certain order, are all-important if this dendritic growth is to produce useful synaptic connections. Since it is impossible to inspect the actual neurones to discover how the connection making is progressing, our best clues, as to whether we are providing effective stimuli, will be the movements and postures of the children. These are the outward expression of success or failure. If they are in any way abnormal for the child's age—that should warn us that somewhere the neuronic pattern needs correction. Some change is needed in the environment—in the stimuli that brain is receiving—an alteration in the method of training, new material in play or work, change in diet, more sun or more sleep. Fatigue may be the factor producing failure in the functioning of the neuronic connections, and so be the cause of temporary abnormal movements and postures.

Movements of the child of one month

So far we have glanced at some movements in the infant before birth and just after. When a month old, there are movements in the baby's face, first about the mouth—where muscles have been active in the acts of sucking and crying and so connections controlling this region will be more advanced—later in the forehead—possibly connected with nerve impulses originating in muscles contracted to move the eyeballs. Such contraction is itself the result of stimulation of the sense organs of the eye (retinæ) by changes in light.

The limbs move with more force and to a greater degree, and begin to effect some mechanical results; an object placed in the hand is not only grasped but movements of the elbow carry the object to the mouth (i.e. nerve impulses, started from the sense organs of touch and pressure in the palm, now find an outlet into motor neurones to other muscles causing the bending of elbow). But, as the object is sucked, impulses find an outlet to other muscles and those controlling the 'grasp' relax.

Movements of child of three months

When the infant is three months old we may observe some control of movements through eyes and ears, the head may turn towards a bright light. Still we do not see the hand move straight towards an object within the field of vision and when a part of the body is irritated the hand does not move towards it. Stimuli cause movements but do not guide them.

The first pauses of attention

During the development of co-ordinated from random or spontaneous movement there appears a most interesting and important sign of dawning mental power. If you are watching a rested and well-nourished baby of some three to four months old, you may see the gentle spontaneous movements of separate fingers, as well as a wandering of the eyes. Then stimulate his sense organs of sight by means of a bright moving object such as a bunch of keys. At once the random movements stop. Then, after a few seconds they may be resumed, even though the stimulus be continued. Perhaps the next time the keys are used to stimulate the retinæ the pause will again occur, but this time after the pause, the hand will be stretched out towards the keys. At a further stage they will be grasped. This pause in the spontaneous movements corresponds to a first mental attitude of 'attention'. It seems likely that during the pause some change occurs in the relationship of neurones—the growth of dendrites due to the passage of nerve impulses in adjacent neurones (see p. 47)—which renders easier the subsequent passage of nerve impulses to that group of muscles which contracts to move the hand towards the keys.

Movements of child of six to eight months

Later on, a baby's movements, e.g. between its sixth and eighth month, shew that it is engaged in such brain training, making neuronic connections or patterns in enormous numbers. Professor Thorndike describes in *Human Learning* how 'each toy is held in scores of positions, moved in scores of directions the eyes observe it again and again so that one rattle, spoon or block is seen in scores of aspects and hundreds of settings. All objects of suitable size are pushed, pulled back, turned over, let fall, picked up, so that these movements enter into thousands of connections.'

Effect of success in causing repetitions

Thorndike says that a baby, in fact, during the first twelve months is engaged in learning in the general animal way by random movements, then by trial movements, where success by its after effects, causes repeated use of the 'successful' neuronic paths. But the baby differs from any other animal in the enormously greater number of its neurones and therefore in its enormously greater possibilities of pattern making.

A baby's babble illustrates both these great possibilities and also the effect of 'success', for it includes more differently articulate sounds than any language, and combinations of these, optimistically interpreted by the family become connected with valued after effects and so are more often repeated, and perfected.

Thoughts developing through movements

To quote Thorndike again: 'Within a year or two the baby that at 12—14 months played like a kitten, only in many more ways, chattered like a monkey, only with many more sounds, and learned like a puppy, only so many more acts and facts, comes to have ideas, think in words about qualities and relations, talk to himself, and plan.'

If you will observe the movements of a puppy playing with a ball and compare with those of a baby, you will see how many more movements are possible to the latter, and how infinitely more delicate they can be, when fingers and hands and moving eyes replace paws and nose and moving head. To the baby the ball becomes a see-grab, see-feel-drop, see-grab-turn-over, see-grab-rub-against-toes, etc., etc., in hundreds of different ways, through the different views obtained by eyes moving freely in both vertical and horizontal directions and through the variety of contacts possible to ten jointed fingers and a palm. The stimulation of all his sense organs in turn produces great gradation and variety of movement. This itself involves stimulation of myriads of muscle sense organs. So neuronic patterns are built up, including groups of neurones in the more recently evolved, slowly maturing cortical layers of the brain on which mental activity depends.

The multitude of neuronic connections made, leads to the idea of ball-in-itself not tied down to any particular connection. You can think out for yourself how much more limited must be a puppy's 'idea' of ball, and begin to understand how movements controlled by external stimulation, as from a ball, may be building up neurones into patterns for purely mental processes.

Iteration and imitation

Again, training of neurones for mental processes occurs with the movements involved in iteration and imitation so constantly observed in young children. Such movements are due to a similar neuronic mechanism to that which was described for the grasp reflex.[1]

Many of the early movements of a small child are repeated again and again. Careful observation shows that this iteration occurs, and the child repeats any of its own random acts, when such acts stimulate its own sense organs, e.g. quite by chance one day baby claps his hands together. The clap makes a sound which stimulates the sense organs in his ears. The nerve impulses thus sent into the brain neurones take the path out *which has just been used* by the impulses which have just caused contraction of the clapping muscles. So out go the nerve impulses started from his ears and he claps again.

Similarly a baby's babble re-stimulates his active vocalizing muscles through his ears and so causes its reiteration.

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[1] See Prof. E. Holt in *Animal Drive*, from which these instances are drawn for readers who are not sufficiently advanced physiologists to cope with the close analysis in this brilliant book.

Just after nursing, a baby's lips are passing from the sucking position into a resting position very akin to a smile. If at this moment the mother—as she very usually does—smiles down at him, he is extremely likely to imitate the smile back. The stimuli coming from her facial movements to the retinal sense organs of his eyes set up nerve impulses which find more open the path recently traversed by the impulses producing the resting position. So the muscles controlling the resting position receive these fresh impulses through the retinal stimulation, contract still further and he echoes the mother's smile. A smiling facial expression becomes associated with pleasant conditions, warmth, nourishment, and his mother's smile.

The same process occurs in the imitative movements of children in the nursery school and infant school stages. If the movements made by another person resemble a child's own random movements and occur simultaneously, it may stimulate the child's already active neurones to produce an exactly echoing movement. This may easily be hailed with delight by the person echoed, the child will be pleased too and this 'success' will lead to further repetition.

Reinforcing mechanism responsible for the failure of the 'don't' type of training

Observations of such iteration and imitation of movement in small children, combined with this physiological knowledge as to how it occurs, warns us that when a child is making any movement, especially of a more or less repetitive, or automatic, 'thoughtless', character, a new stimulus may easily increase such movements. The nerve impulses such a stimulus sets up, find the motor path out to the already active muscles more open than others. This explains the failure of much admonition of the gentle nagging kind.

Tommy is trying to tear up pages of a valued book, Mother says: 'Tommy don't do that.' This only, quite literally, sends further impulses—via the auditory neurones to the very motor neurones concerned in the tearing movements, reinforcing the undesirable action! Of course a sharp smack may momentarily produce the required effect—by causing all nerve impulses to spread through many synapses at once in the old infantile random way—tears, screams and struggles result. As Professor Holt says in *Animal Drive*, its a 'Blunderbuss method' and quite uneducative. If you have persisted in the first gentle admonitory method Professor Holt declares that next morning, 'while the child is innocently thinking of cabbages, and kings, if you say: "Tommy don't do that," you may see him walk over to the book and begin to tear it!'

The best way to deal with such incidents is to prevent them by only having rag books within reach at the tearing stage and plenty of valueless tearing material also available. But, if undesirable movements are in progress, the distracting to be successful must stimulate at once to some other movement, be embodied in fact in an attractive 'Do' not a 'Don't!'

How imitation can help rapport between teacher and child

The imitation of your movements by a child means that the neurones of its brain are, to that extent, functioning in the same way as yours, and, if the copying is done willingly and energetically, this leads to increased rapport and more willing obedience.

What has already been said suggests how careful observation of a child's movements can show you how to start such willing educative imitation.

Since from two to five the child's movements are largely echoing and imitating you, begin by copying one of *his* movements, with a smile but no words—so suggesting a game.

He will imitate you back making his own movements more energetically than before—for extra stimuli to the retinæ of his eyes from your movements and also stimuli from sense organs in the contracting muscles which move his eyeballs, now send in extra impulses to his brain. These will find their easiest outlet by the motor neurones already activating the muscles in the movement you imitated. So his movement becomes more energetic. When the 'game' is in full swing you can introduce any new movement that you want him to imitate. You will find the whole process greatly helps your control over him and from then on his imitative movements will increase. The adult's chief problem then becomes the provision of good models in movement and posture to be imitated.

CHAPTER II

DESCRIPTION OF CHARACTERISTICS OF BRAIN ACTION

(With examples from Teaching Practice).

Neuronic pattern defined according to method of formation.

Structural patterns

hen neurones are well nourished and have recently been active owing to the passage of nerve impulses through them, then the passage of a fresh nerve impulse, set up by an external stimulus along one of these recently active neurones, causes growth of dendrites in the other neurones towards the newly activated one. Such growth is always from the motor side of the synapse, i.e. in the opposite direction to the direction of the nerve impulse.

Through such dendritic growth synapses may be said to become functional, in the sense of allowing impulses to pass through them in a certain direction, and the group of neurones comes to act together, forming a structural pattern. For our immediate purpose a structural pattern may be said to be such a linking up of a certain number of neurones that they tend to be activated together and in a certain order by external stimuli. This process occurs in the building up of the earliest structural patterns which become permanent for the control of reflex movements (see Grasp Reflex p. 37). They form the basis of a large proportion of the patterns active in postures and in the movements of creeping, running, walking, etc.

But the individual shows great variety in his response to the external stimulus, even in these more or less stereotyped movements and postures. The Patterns then activated may be called Physiological to distinguish them from the older structural ones.

Physiological patterns

These underlie all mental activity, including 'voluntary' variations in movements and always include neurones in the later evolved cortical layers of the brain. These become integrated with the older structural patterns via the pyramidal cells (see p. 60) and, through them, control posture and movement. To account for mental activity and the power to vary response to stimuli, we have to suppose that these neuronic patterns giving that power are somewhat differently built up from the older structural patterns. These later formed cortical patterns can be dissolved and their neurones enter into new patterns. So, it seems probable that, in their case, the pattern is not formed by growth of dendrites, but in some other way, possibly by amœboid movements of dendrites at the synapses.

Such movement may be brought about in just the same way as the growth of dendrites in the structural patterns, i.e. by nerve impulses set up by an external stimulus (see p. 46). These nerve impulses, arriving at an active well-nourished group of neurones, cause them to form a physiological pattern through amœboid movements (or some other change) of the dendrites. Later by retraction of dendrites the connections may dissolve in whole or in part, so that the component neurones can form fresh combinations for new mental acts.

Differing views as to the origin of spontaneous cortical activity precedent to arrival of any nerve impulse due to external stimulus

Some authorities hold that cortical activity is often spontaneous, i.e. originates in the cell bodies of the neurones concerned, when these are in a state of high nutrition. Others believe the activity is brought about by the streams of nerve impulses continually pouring into the cortex from sense organs in the contracting muscles of heart, lungs and alimentary canal, as well as from the skeletal muscles.

In either case the growth or amœboid movement of the dendrites to form structural or physiological patterns depends on good nutrition with some activity in the neurones, followed immediately by the arrival of nerve impulses due to stimulation of a sense organ by the external environment.

Neuronic patterns may be primary, secondary, tertiary, etc.

For illustration we may compare, as far as knowledge allows, what occurs among the cortical neurones when (1) a baby bends a finger spontaneously (see pp. 34 and 117), with (2) what happens in an imitative bending (see p. 62), (3) a similar bending following an auditory stimulus and (4) bending of a finger during a creative act.

(1) Pattern governing bending of a finger in spontaneous bending

e.g. Pattern of neurones involved when a baby bends a finger spontaneously.

Certain muscle fibres have contracted and others have relaxed to produce such bending. This activity was brought about by nerve impulses reaching these muscles along motor nerve fibres of motor cells in the spinal cord. These motor nerve cells have many finely branching dendrites which are intermingled with branching ends of axons. These axons are the nerve fibres of neurones bringing nerve impulses from many different sources, for it is possible for nerve impulses set up by stimulation of any sense organ to reach these motor neurones in the spinal cord and pass out to the muscles.

Various sources have been suggested for the stimuli which bring about spontaneous bending of fingers in the young baby. As far as can be seen they have no external source such as light or sound.

Some physiologists think the nerve impulses actually originate in the nerve cells of the brain cortex, as the result of changes in the living substance, when well nourished, and, in this belief, describe these movements as spontaneous.

Other authorities hold that these cortical cells first receive nerve impulses, themselves the result of stimulation of muscle sense organs, perhaps in the alimentary canal, where contractions frequently occur during digestive processes.

In this latter case the course of the nerve impulses might be as follows. Nerve impulses from muscle sense organs in the alimentary canal reach motor neurones in the spinal cord, travel out by them to muscles which contract, and so cause some finger to bend, a 'random' or 'spontaneous' bend. Nerve impulses, thus set up in muscle sense organs, return to the spinal cord and some of them travel up the cord to reach at length a small group of neurones in the brain cortex. These are some of the so-called pyramidal cells which have enormously elaborated dendritic terminals.

Nerve impulses, passing via one such group of pyramidal cells, will eventually reach motor neurones in the cord controlling the bending of one finger, while those passing via another group of pyramidal cells cause bending of another and so on. At this stage in development, nerve impulses, as from some muscle sense organs, reaching these pyramidals will spread fortuitously and any finger may bend as a result. Sense organs in its muscles will again send back impulses to the cortex and, *after a pause*, the process will be repeated, first one and then another finger slowly bending, as first one small group of pyramidal cells and then another sends out nerve impulses and rests. Here a small group of cortical neurones acts together to send out nerve impulses through a successive chain of neurones in the cortex and spinal cord, ending with a small group of motor neurones in the cord, controlling the contraction and relaxation of a few muscles.

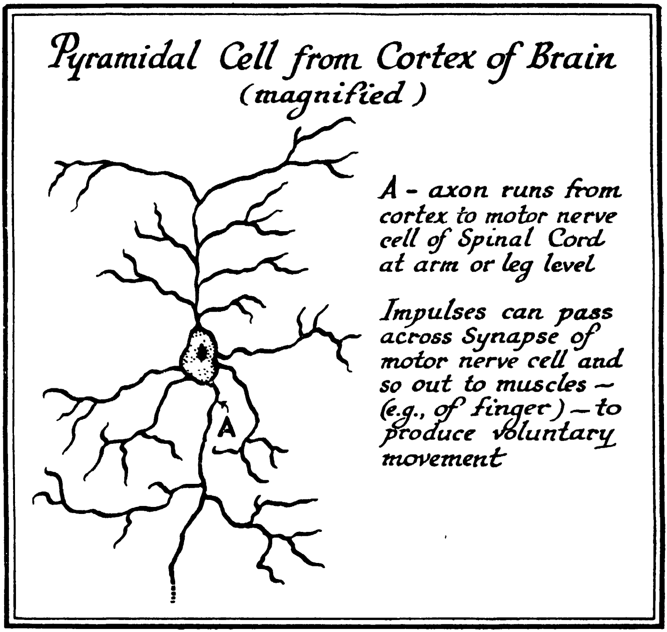
Pyramidal Cell from Cortex of Brain
(magnified)
A - axon runs from cortex to motor nerve cell of Spinal Cord at arm or leg level
Impulses can pass across Synapse of motor nerve cell and so out to muscles — (e.g., of finger) — to produce voluntary movement
A

DIAGRAM VII

All the neurones involved form a comparatively simple co-ordinated neuronic pattern. The group of pyramidal neurones in the cortex probably never becomes a structural unit with fixed connections for bringing about this particular movement, as have the succeeding neurones in such a pattern. The characteristic features of the brain action in the spontaneous or random bendings of the fingers are:

1. That one small group or pattern of cortical neurones sends out nerve impulses to muscles and then another.
2. There is little or no interaction between patterns of neurones in the brain cortex.
3. The ultimate course of the nerve impulses from the cortex is not directed by the original stimulus.
4. If there is such a stimulus at all it is not of external origin. Hence the movements may be described by the observer as aimless.

(2) Pattern governing bending of finger in imitative bending

We may now compare with this the pattern which is involved when a child of five to seven bends a finger in imitation of a teacher. The child stands and is told: 'Do as I do.' The seated teacher stretches out his own right hand, in front, level with his shoulder, hand palm down, each finger straight, thumb not drooped, i.e. a 'straight balanced hand' (chap. IV, p. 143). He separates his fingers and slowly bends the first finger (say) at the knuckle (see p. 173, Exercises, Chapter VI). In the course of getting the teacher seated with the child standing in front, auditory and visual stimuli will have rendered active many patterns of neurones in the child's brain and spinal cord.

The final auditory stimulus 'Do as I do' activates patterns already built up during previous acts of imitation.

From such primary patterns a secondary pattern is produced embodying the idea of imitation (cp. idea of 'ball', p. 52) where this idea is not attached to any particular act. We do not know by what physiological process this abstraction is brought about. The process must include the dissolution of some neuronic connections and the forming of fresh ones. Such building up of secondary from primary patterns may be called *compound cerebration.* In the spontaneous bending of fingers by the baby there was no compound cerebration, and in the imitative bending when the teacher proceeds to bend successive fingers and is imitated, after the first act of imitation, there may be no compound cerebration.

The compound cerebration caused by the auditory stimulus 'Do as I do' then eventuates in certain patterns. These include structural patterns controlling movements, which fixate the child's eyes on the teacher. Then the movement of the teacher's finger sends light rays to the child's retina whence nerve impulses pass to a group of neurones in the cortex, causing visual sensations. *There will be a pause.* Interaction, between the neurones in the visual sensation group, and those activated by the auditory stimulus, will occur, forming a new temporary pattern. Then impulses from this temporary pattern pass to the small group of pyramidal cells, which by sending on the nerve impulses to the spinal cord brings about the bending of the finger. From the pyramidal cells onwards the pattern of neurones used may be the same as in the spontaneous bending.

In these last steps there is interaction of a few groups of neurones in the cortex, but this interaction is guided in its course by external stimulation either auditory or visual. The time and quantity of movement in the child's bending finger, if it is the same as that in the teacher's, indicates that the groups of his neurones are acting in the same order and way as those of the teacher. After the movement begins, there need be no thought process, no compound cerebration. Groups of neurones act successively in order guided by a visual stimulus, i.e. there is *co-ordination* of visual sensation patterns with patterns controlling the muscles that move the finger.

Comparing this imitative bending with the first example of the spontaneous bending, gives the following points.

1. There is interaction between various groups of neurones in succession, before the nerve impulses arrive at that group of pyramidal cells through which the impulses must pass to cause bending of the particular finger.

2. As a result of this interaction the nerve impulses leave this group in such order, and are of such intensity, that they lead to a contraction and relaxation of muscles producing the same time and quantity of movement of the finger as that produced by the nerve impulses from the teacher's pyramidal cells. This means that

3. The ultimate course of the nerve impulses and their intensity is directed by external stimuli received from the teacher's bending finger.

(3) & (4) Pattern governing bending of finger in creative bending

This involves much compound cerebration as retained patterns are reactivated in turn. First compare with the spontaneous and the imitated bending the happenings when a child is told:

'Hold out your hand in front of you, level with the shoulder and bend the first finger as you did yesterday.' Here the train of brain action is only started by the stimulus, not directly guided by it, as in the imitated bending. Many patterns for the sounds and meanings of words had been previously built up by every variety of stimulus and these are now reactivated and secondary or tertiary patterns abstracted from them. There may be a *long pause* while the compound cerebration required occurs.

Concentration of nervous energy to control the movements required will probably exclude any possibility of spontaneous activity among the neurones.

But suppose the child bends its fingers in some *creative* activity, e.g. with plasticine.

Here the sight, smell and touch of the plasticine may furnish the stimuli which activate many already formed patterns, but these stimuli only partially guide the nerve impulses, there will be the chance that spontaneous nerve impulses will also activate new patterns, and that any part of the environment may stimulate others, so that much compound cerebration may go on before the fingers bend to create the final form.

The preceding descriptions of brain activity illustrate how spontaneous movements and imitated movements train cortical neurones to control the later movements of creative activity. Spontaneous thoughts and imitated thoughts train the neurones for the creative thoughts which must precede creative movements.

The mental processes which are the basis of intelligent number work are such 'imitated thoughts'. The teacher of arithmetic in the early stages has to present stimuli to the child so that its neurones are built up into definite patterns resembling those in the teacher's own brain. Lessons have to be prepared to ensure the giving of stimuli in the right order and of the right intensity to produce these patterns. The child must be physically fit to receive those stimuli. Examples are given in the following pages to illustrate how certain stimuli can help to build these essential early patterns.[1]

Co-ordination and compound cerebration illustrated by the processes occurring while a child is learning to count

The child has been learning to sing or say the (to him) meaningless jingle, 'one, two, three, four'. He may repeat this ditty while marching or clapping, 'One, two, three, four, one, two, three, four,' etc., etc.	Here the auditory stimulus of the teacher's voice makes the child imitate, producing a pattern of neurones which controls the vocalizing muscles for one, two, three, four. These patterns form a co-ordinated series, a pattern resembling that in the teacher's brain, and formed without compound cerebration.

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[1] The writer here desires to stress the fact that she lays no claim to expert practical knowledge of the best methods now in use among teachers of elementary number work. The examples

One day the teacher has 3 or 4 large beads on a frame, similar to one on the child's desk. Says 'Look' and points to a bead, gets child to imitate.	
Child sees a bead.	Certain neurones are thereby linked in a physiological pattern through stimulus of light rays from the bead-pattern S.
Next instant child moves his hand and points to a bead, imitating the teacher's movement.	A second neuronic pattern is built up by muscle sense, pattern M. Pattern S. is linked to pattern M. by a similar chain of neurones to that which linked S. and M. in the teacher's brain. Again pattern S.-M. built up by imitation, i.e. under guidance of teacher's movements is a case of co-ordination, no compound cerebration need have occurred. Neurones were co-ordinated to form patterns S. and M. respectively, and patterns S. and M. were co-ordinated by external stimuli to form pattern S.-M.
Having seen teacher point in succession to a row of beads, child proceeds to point to each of his own beads in turn.	Here a series of uniform repeated movements occur of eyes, of hand, of arm, and a series of similar temporary physiological patterns must be formed and dissolved. At this

given in Ch. II are meant (1) to draw attention to the physiological processes involved in laying foundations for mathematical conceptions; (2) to provoke consideration and discussion of various methods.

stage we have no reason to conclude that any counting has occurred, or that the child has any awareness of how many times his unit of movement has been repeated.

It comes one day as a complete surprise to the child, when he is quietly watching, to find his teacher saying, very slowly, and clearly, while pointing to the familiar beads in the familiar way: 'One, two, three, four', moving each bead then a tiny bit sideways before saying the next number. He imitates with his own beads. She repeats the process and finishes by saying 'Four beads, count yours again.'

Next she counts: 'One, two, three, three beads. Now you count these beads.'

He does so.

'Count four beads', and so on.

Only when the child's movements and words show that he distinguishes clearly between 3 and 4 beads can we conclude that patterns which 'mean' three and four have been formed among his neurones. Here something more than co-ordination has occurred, something that may be called compound cerebration. The primary patterns for the words 'three' and 'four' have been momentarily detached from the permanent pattern for the co-ordinated series of numerals, and have been integrated in turn with the patterns controlling the movements of eyes and hands, three and four movements respectively.

Another analysis of processes occurring in a child's brain during possible 'lessons' on 'counting'

N.B. [Everyday experience, games and stories, will already have built up some of the patterns among the neurones in the child's brain, which are needed in counting, but, for the sake of simplicity, it is assumed that none of them have been formed.]

The teacher has large wooden beads on a frame. The children exactly similar beads, equally spaced, in a line on each desk.

1. Teacher says 'Look' and points slowly to each bead on frame in succession. This can be done with each hand in turn.
2. Teacher says 'Do what I do'. Again she points to each bead in turn with children imitating her.

In 1 and 2 there should be no mental action, no compound cerebration, only the co-ordination of relatively few neurones in a pattern to control a succession of similar movements.

Each movement causes the return of nerve impulses from the same muscle sense organs to the same neurones.

3. Teacher claps her hands a certain number of times, with children imitating.
4. Teacher taps with one hand on palm of other, children imitating.

In 1, 2, 3 and 4 neurones are being trained to send on impulses in certain series, patterns are being built which will be needed in (6).

5. Children are taught the names of the numerals 'one'. 'two', 'three' . . . . . . in their correct order of succession.

Here auditory stimuli build up, as a mere bit of jingle, separate neuronic patterns controlling the saying of each name. These patterns adhere each to the next in the series, so that later on the stimulus of the sound', 'Count', or of 'one', sends nerve impulses from pattern to pattern each starting off the next in the series, the impulses following the same course as the original impulses. The whole of each pattern is roused to activity again, there is *co-ordination*, as in most learning 'by rote', but no compound cerebration. For such a series to be revived and reproduced in the same order, each component must be separately built up by adequate stimulation, without haste and without undue emphasis.

6. Children are taught to count the beads, and express the number of beads seen.

To do this—teacher and children have frames each with four beads, say. Teacher has four beads spaced on her frame, and says 'Look'. Then, in a low voice, 'one', 'two', 'three' and more loudly, 'four', pointing slowly to each bead in turn. Then teacher says: 'You count too.'

Children imitate.

Process is repeated, with different numbers. Next, the pointing is omitted but good spacing of objects is kept to encourage eye-movements.

Another time 'birds' may be drawn on blackboard at good distances apart and counted, using eye-movements, as teacher points to them. Replaced by another set and these counted without teacher pointing in answer to question:

'How many birds have I drawn?' 'Count them.'

Oranges, nuts, a row of children may be counted. A child comes out and claps, while class silently watches, and then: 'Hands up those who know how many claps.' Two children out, one taps on palm of the other who has eyes closed. 'Hands up, for how many taps.' Does the child with closed eyes say same number? These methods gradually build up an established *order of compound cerebration.*

In this building up, the direction 'Count' leads the children to *pause*, then to imitate the movements of the teacher's hands, fingers, eyes and vocal cords.

Thus, under direction (i.e. through the stimulus of the teacher's voice and movements) the primary patterns of neurones already formed for controlling the muscles contracted to vocalize 'one', 'two', 'three', 'four', etc., are integrated in turn with the patterns controlling the successive movements of eyes or hands. So secondary patterns are built up.

The secondary pattern for 'four' will, because of the more intense stimulus, be more enduring than those built up by the whispered 'one', 'two', 'three'.

Repetition of the process using different numbers builds up many such temporary secondary patterns.

In each of these the pattern controlling the vocalizing of the name of the numeral is momentarily detached from its place in the permanent co-ordinated series 'one, two, three,' etc., and is attached to the temporary pattern that has controlled the repetition of movements for which the particular name stands.

We do not know what change in the neurones represents a 'sensation' of repetition, any more than we know the physiological counterpart of visual or auditory 'sensations'. We can see, however, that there must be a summation of stimuli to the same neurones, from the sense organs of the muscles producing the same repeated movements of hand or eye in pointing and looking. The discussion of the Grasp Reflex in Chapter I has indicated why such stimuli from muscle sense organs are necessary for clear ideas of number. That is why emphasis is laid on the need for making use of uniform repeated movements in this early stage of counting.

After many temporary secondary patterns for the final numeral in counting have been thus built up, further compound cerebration must be inferred to have occurred, for we find that the direction 'Count' has come to mean to the child, this finding of the numeral for the final number of the objects presented.

We do not know the exact physiological process by which this permanent secondary pattern for 'Count', this 'meaning', has been built up. We do know that, for a correct meaning and for the ability to respond correctly, the preliminary patterns must first be built up, viz.:

1. The co-ordinated series of patterns for the names of the numerals in order.
2. Temporary patterns registering via muscle sense a number of separate distinct movements, e.g. of eyes moving from object to object, of hands clapping, of fingers tapping.
3. The integration of these primary patterns to form secondary patterns in which the pattern controlling the saying of the numeral integrates with that controlling the appropriate series of movements.

Only through some such directed counting of great varieties of objects, on many occasions, will children arrive at that idea of abstract number which must be the basis for later arithmetical processes.

Compound cerebration has to abstract the idea of the 'three-ness' of three for example from three boys, three pennies, three beads, three oranges, etc., each set having been counted by three similar movements. It is the similar stimuli produced by the same number of similar movements which gives its 'three-ness' to three.

'Three-ness' is the only common factor in such a series of patterns in each of which it must be represented by the effects on the neurones of nerve impulses due to three definite movements. The compound cerebration involved in abstracting the idea of three-ness is only to be expected at a much later stage than that of the counting processes themselves, as already set out and summarized in 1, 2, 3 above.

Teaching the meaning of 'greater than', 'less than'

In counting (see p. 66, etc.), the child moved its eyes in looking at, and its fingers in pointing at, objects in succession, and so patterns due to the stimulation of muscle sense organs were built up. At some stage long after this the teacher may then say: 'We call 3 greater than 2', '4 greater than 3'.

The 'feeling' of repeated activity in looking and pointing, helps to give meaning to the new neuronic patterns set up by the auditory stimuli: 'We call 3 greater than 2,' etc.

But before a child can acquire at all a comprehensive notion of 'three-ness' and still more of 'moreness', greater-than-ness, etc., he must also have repeatedly experienced 2 and 3 quantitatively as well as numerically. After much concrete experience a new pattern is formed by bringing the two primary patterns for two and three into activity at the same moment as a new pattern for 'greater than' is being built up by the stimuli of the sounds. Two sets of movements which were involved in every concrete situation with 2 and 3 will be compared as to the amount of neuronic activity required to produce them. But what actually happens to nerve impulses, neuronic patterns and their synapses, in such an act of compound cerebration is unknown.

The *directing* statement bringing about such interaction is very necessary, if future mental confusion is to be prevented. It abstracts the common factor from all the previous concrete physiological sensations obtained by 'feeling' weight of 2 and 3 ozs., moving arm two and three times, moving finger and eyes to count two and three objects, etc. It links this abstracted factor to the pattern for the adult convention 'greater than'.

Illustration of pattern building from lessons in teaching a standard of measurement, feet. (See p. 105 for inch.)

The child has been taught to count and knows the meaning of 'greater than' 'less than'

Child and teacher each have sticks, one foot long, lying in front of them on their desks.

Teacher says:

1. Look along your stick from end to end.
2. Shut your eyes and feel along the stick from end to end, with one finger.
3. Open your eyes and feel again.
4. We call this length 'one foot'.
5. Feel along it again. What do we call it?
6. Bring out your one foot stick and use it to chalk one foot on the floor. (If the floor is of boards, if not, on sheets of brown paper pinned down with drawing pins).
7. Join another foot to the first, end to end.

8. Look from end to end of the new line.
9. Feel from end to end of the new line.
10. We call this length 'two feet'.
11. Make the two foot line into a three foot line.

Using some such directions as have been suggested above, as auditory stimuli, primary patterns for each length are formed by stimulation of ear, eye, and muscle sense organs. Next the auditory stimulus, received when the name ('one foot', etc.) of each length is said, brings about compound cerebration and the formation of secondary patterns. In these the degree of each primary pattern now adheres to the numeral used for its expression. We do not know the exact physiological process by which degree is thus abstracted from all the other sense impressions included in each of the primary patterns, e.g. the roughness, colour, etc., of the stick.

Each direction 'we call this length one foot', etc., emphasizes the only difference between the primary patterns, i.e. degree, so the direction will reactivate especially those neurones which were originally concerned in the registration of degree. These will be the patterns controlling the measuring movements of eyes and fingers, they will now become coactive with the patterns produced by the statements giving the name of the particular length and so will tend to adhere to it.

The direction 'Make the two foot line into a three foot line' obviously will allow for some spontaneity coming into play, for the third foot can be added at either end of the two foot line, or even drawn without use of the stick.

There must be further drill in repeating the same order of impressions for 1 ft., 2 ft., 3 ft., etc., with the expression of each member of the series by its numeral. Thus a firmly adhering series of patterns is built up forming an established standard for comparison.

The child can then use the standard to find the number of feet in any accessible articles, he may first estimate by eye and finger movements what member of his established standard coincides with his measurement and then confirm by use of his foot-sticks.

This allows for much spontaneity and quickly leads to the discovery of the need for inches to express fractions of the foot. (See pp. 65 and 105.)

The meaning of 'greater' and 'less than' can later on be further impressed by directions to discover which has the greater length of two given articles.

A child who is able to tell at once which is the tallest of himself or two other children, or which is the longer length of two ribbons still often needs special direction later on in building up these neuronic patterns for 'greater than' and 'less than'.

Possibly a good point at which to begin the building up of such a pattern occurs in teaching the order of numerals, though perhaps this may be far too early to introduce such an abstract idea, and no definite pattern may be built.

A child may swing his arm counting 1, 2, 3, 4, then stop.

Then may swing his arm counting 1, 2, 3, 4, 5, 6, 7, 8.

Then be taught to say '8 times is greater than 4 times', and so on. Here the pattern for each movement needs the same physiological work, and 'greater than' is represented by a secondary pattern abstracting and comparing the total effect of each series. Later on still a single term covers both effects when the child learns '8 times is twice 4 times.' (See also pp. 92, 104, 107.)

Teaching the meaning of 'compare'

Comparison is so important, that a clear understanding of, i.e. a permanent pattern established for, the direction 'compare' will prove very useful. So at some stage such directions as 'compare the lengths of 5 feet and 3 feet' should be shown, to require the answer '5 feet is greater than 3 feet by two feet', and so on.

An act of comparison

A child (age 5) has previously acquired the sounds 'weight' and, heavier', with no meanings given. He has not been taught 'ounce'. Then he is made to feel the weights of pillboxes of 1 oz., 2 oz., 3 oz. etc., up to the 8 oz. placed successively on fingers of his outstretched hand (for details as to boxes, etc. see p. 101).

The only words used are 'Feel the weight of this box like this', teacher showing him first on his own hand. Then, 'Feel the weight of this one' till all eight boxes have been felt.

Then he is told. 'Hold out both hands.'

The 1 oz. box is placed on fingers of one hand, the 8 oz. box is placed on fingers of his other hand. He is asked. "Which is more?"

When he has correctly described his impression he is told: 'This weight is heavier than that one'

The same remark follows the use of the 4 oz. and

6 oz. boxes, the 2 oz. and 5 oz. boxes and so on. The hand receiving the heavier box is sometimes the right, sometimes the left.

Next the 1 oz. box and the 8 oz. box are used again. This time the teacher says:

'Give me back the heavier weight.'

There will be a pause.

If he then gives the heavier box certain facts are clear about the patterns formed by his neurones.

a. Primary patterns have been formed corresponding to the weight of an ounce and of eight ounces. Each pattern includes that for the sound 'weight'.

b. A primary pattern has been formed for the sound 'heavier'.

c. A primary pattern has linked 'heavier' momentarily to certain weights.

No compound cerebration has been involved so far, as all these patterns were formed under directions and are the outcome of stimuli, either through ears, for the words 'heavier, weight', or through muscle sense, for the felt weights.

d. Compound cerebration occurred, i.e. interaction between the three primary patterns, for 1 oz. wt. 8 oz. wt. and 'heavier'.

Probably cortical neurones at a 'higher' level in the brain also took part in this interaction. Thus a secondary pattern has been formed which becomes the neuronic basis of the child's act of comparison and choice as he gives the heavier weight.

In this secondary pattern the respective *degrees* of the weights of the 1 oz. and 8 oz. boxes have been abstracted from the primary patterns.

Another illustration of compound cerebration leading to comparison and choice occurs in the teaching of colours in the nursery school stage.

Comparison and choice in teaching colours

One day the child is supplied with bits of paper or wool of no particular shape or size but all of one particular colour, and a little later having removed the first set, other pieces of a different colour can be presented.

On another day names of the colours can be taught by getting the child to look at and imitate the movements of the teacher's mouth, as the name is heard.

Next day a bit of coloured paper, red say, can be given and the child as it looks at the paper can say 'red' as it hears the teacher say the word, and so on with the other colours.

Then the word 'colour' may be taught and associated with 'red colour'—'blue colour', etc., each with its own retinal stimulation. Later on, when a child is told to 'pick out all the red colour' from a number of differently coloured bits of paper, compound cerebration occurs, i.e. further interaction among the different neuronic patterns representing red, yellow, blue as the child compares them and picks out the red colours. Still another even more complex interaction occurs when he is asked to 'pick out the colour you like best'. Carefully planned stimulation of one sense at a time greatly simplifies early acts of comparison and choice, because the basic patterns among the neurones have been well constructed for the purpose.

Choice may not involve any mental act or such interaction among neuronic patterns as can be called compound cerebration. e.g. When a very young child 'chooses' a bright, in preference to a dull object, there is no compound cerebration. The stronger stimulus controls the observed movement. The temporary pattern which has resulted in a sensation of brightness is co-ordinated with the structural pattern of neurones controlling the movement.

Contrast the amount of compound cerebration which must occur when a child is asked: 'Shall I read to you?' This may activate hosts of patterns representing a dull tale, disliked yesterday, these will interact with already active patterns due to recent movements in a rowdy game. After a pause the resulting compound cerebration controls the movements of the vocal chords for the sound 'No!'

Functions of directing words or phrases in the building up of patterns

1. In teaching the baby to speak.

A baby has already responded to many stimuli from the object or person before his mother or nurse teaches its name, e.g. take the word 'Mummy'.

First the baby builds up many patterns through his responsive movements to stimuli received from his mother through touch, sight and sound. Later in his babble he often reiterates 'Mum', 'Mum', 'Mum'. Then his mother or nurse will say the word very clearly turning it into 'Mummy'. He at once easily copies this because at the moment most of the necessary neurones are already acting in just the right pattern (see pp. 38 and 53). Thus a new primary pattern is formed by the adult's directing word 'Mummy', for this sound produces nerve impulses almost simultaneously in neurones connected with the sense organs in the ear and in neurones from the sense organs in the vocalizing muscles. Later on, the baby is again induced to say 'Mummy' when the other primary patterns connected with her, due to touch, sight and sound, are being revived, as she nurses him. So these already built up patterns for his responses to these stimuli become integrated in turn with the new primary pattern for saying 'Mummy'.

So far there may have been little compound cerebration. Gradually, by constant association of only certain stimuli with the stimulus received in hearing, and in himself saying, the word 'Mummy' abstraction of parts of the original patterns occurs and these are connected up to form the secondary pattern associated with the word 'Mummy' as its meaning. This is the process of compound cerebration or abstraction from primary patterns to form a secondary pattern.

'Daddy', similarly learnt, is usually applied, without such a process of abstraction, to all males, long after 'Mummy' has become the responsive outcome of a secondary pattern applying only to his mother.

Here the directing word 'Mummy' given to the baby by nurse and mother, has directed the process of abstraction, or formation by compound cerebration, of the secondary pattern from his primary patterns.

2. *Function of directing words or questions in school.*

The same process occurs later on in school. The teacher, in preparing a lesson, plans first to build up primary patterns among the neurones, possibly by stimulating only one class of sense organ at a time. She follows up that process with words of direction or questions very carefully chosen to act as stimuli which will cause interaction between, and abstraction from, the primary patterns (compound cerebration), resulting in the formation of secondary patterns, e.g. a child looks at and feels the lengths of two sticks lying on his desk, one 12 ins. the other 6 ins. long. He thus gets two sets of impressions of length through muscle sense, but the patterns built up include neuronic representation of other stimuli received from the colour and texture of the sticks. The direction 'Compare lengths', will at once render most active the neurones which have previously been connected with measurement. Physiologically, compound cerebration occurs, resulting in a mental act of abstraction, which makes the child say one stick is 'half the length of the other'.

The secondary pattern of neurones, which controls the vocalizing muscles in saying 'half the length of the other' still possesses the class (muscle sense) and degree (here degree of length) of the original primary patterns, but it has been freed from those parts of the original patterns which represented colour, texture, and order of reception of the original stimuli. *Direction* is especially necessary for this process of *freeing secondary patterns from the original order of formation of the primary ones.* If this is not successfully accomplished mental confusion results when attempts at comparison are made. At the same time if primary patterns are to be a basis for the appreciation of degree, the order of their original impression is very important.

e.g. 1, 2, 3, 4 lb., 1, 2, 3, 4 feet, etc., should first be felt or seen as the case may be, and retained in their right order. Later it is equally important that, by good direction, the primary patterns should be freed from that order and temporary secondary patterns built up.

A primary pattern will represent:

1. The class (depending on the sense organ receiving the stimulus)
2. The degree (depending on intensity or duration of the stimulus) and
3. The order of reception of the stimuli.

Direction has to free the secondary pattern from whatever is inessential for the secondary pattern that the teacher desires to be built up from the primary patterns.

Value of Direction.

1. It should prevent mental fatigue.

This is fatigue of neurones in the cortex often due to uncontrolled spreading area (see pp. 111 and 127). Obviously direction must be clear, and contain only such words as will reactivate the desired patterns and those only.

2. It should prevent (inhibit) the immediate expression of any impression, i.e. the too quick response to any stimulus. Good manner in direction should lead to a pause, without outward movement, giving time for the stimulus to have its full effect in the building up of secondary from primary patterns.

An example of too quick expression

George was nearly seven years old. He was 'very slow', said his class teacher, and his ambitious parents. I found that he always repeated aloud the question he was asked, before he tried to answer it.

There would seem to be two possible explanations here.

1. It was an infantile form of imitative immediate expression of an impression, and actually prevented the compound cerebration involved in 'thought'.
2. It was a protective device, unconsciously adopted by a brain slow to receive impressions, needing a longer time than usual for the pause required by dendrites for interaction, after the impulses had reached them.

In either case it was desirable to train the neurones to inhibit such outward immediate expression.

He could read fairly well and was very proud of it, though very diffident as to his other powers. I always gave him his little questions in writing and left him to think, while I dealt with someone else. I also saw his mother and told her he always 'needed time to think but had good brains'. I found his eye-movements were slow, the pause before responding in imitative finger exercises was abnormally slow.

Practice improved these remarkably. He showed decided improvement all round after a month's exercises, his teacher reported he was 'interested and more alert and from being an ungetatable child he now talks confidentially and tackles difficulties'.

I suppose then that George had neurones which needed a longer pause than most brains require, for the making of dendritic connections. Parents and teachers had rather tended to hustle his response and his own unconscious protective device of repeating the question defeated its object by giving a direct motor path out to nerve impulses which might otherwise have been building up more useful connections.

In his case, oral direction, the more usual form for a child of seven, was advantageously replaced by written direction so that he could pause as long as was necessary before replying.

Directions need to be deliberate

A quiet unhurried way of giving directions or putting questions is necessary. Such a manner helps to prevent over-stimulation and spreading area with its frequently too rapid finding of a motor path out to muscles, and the resultant 'silly' thoughtless answer. Deliberate directions encourage the necessary pauses for compound cerebration.

For the teacher to be seated during a lesson was once a crime, but with a young, excitable, (i.e. easily over-stimulated) class, direction is often more effective in getting the desired pause before response, when the teacher is seated.

Effect of early overstimulation

There is much danger of this in these days. Adults present a rapid succession of glittering, moving objects with much noisy comment, to the attractive baby. The rapid, crowded traffic, the cinema, the noisy wireless, the crowded home all mean exciting stimuli and far too many nerve impulses traversing the child's immature neurones in rapid succession. So there are too few and too short pauses to allow most of such stimuli to effect good synaptic connections. The eyes make quick, inadequate response movements, and later on, extra movements in foreheads, fingers, shoulders, etc.

bear witness to spreading area of brain action and a waste of valuable spontaneous nerve impulses.

Some such early over-stimulation may have accounted for the type of brain action which was occurring in one child who had difficulty in learning to read.

A child who had difficulty in learning to read

James was seven years old. I had chosen him out of a class of forty children for special exercises (see p. 170), because I observed signs of spreading area of brain action in his many extra movements, corrugation, fidgeting feet, shrugging shoulders, etc.

I was then told that, though he appeared intelligent in oral work, he was very backward in reading. His work in mental arithmetic was fair but his written work very inaccurate. His teacher said that his mental arithmetic itself suffered, 'because his hand always shot up to give the answer before he thought'. I found that when he was asked to read to himself some sentence that he had already read, he always read aloud if he possibly could and only stared about if told that he must not read aloud. When I asked him to read to me a card containing the appropriate picture and the following words: '*Tom* has a boat, it is *painted red.* He *rows* it to the *land.* The waves *help* him.' James had to be told all the italicized words.

Having thus 'read' it once, he could repeat it from memory, but usually he could not recognize a single word he had been told, when shewn it apart from this memorized context.

The words of the card, impressed through his ear, formed a co-ordinated series of patterns of neurones adhering in the order of their original impression, but there had been no interaction between these patterns and the patterns of neurones produced by the visual stimulation of the retina by light from each word. There had been in fact no compound cerebration integrating auditory patterns, visual patterns and the already existing patterns for the meaning of each word.

James was mainly using the old neuronic patterns which he had first built up as a small child when he imitated the sounds of words. It is significant that his ear for music was particularly good.

I next investigated his way of learning to spell. I found that he could spell such a word as 'boat' after he had looked at and spelled it aloud after me (phonetically), but only if I gave him the first letter. The letters when heard produced patterns which adhered in order but he needed to hear again the first letter to start the series.

This would be of no value to him in later work, so I then taught him always to say the word first, which he was learning to spell thus:

'Boat, b, o, a, t, boat.'

Later on in dictation this method would help him to start off the co-ordinated series of patterns, already built up. In learning to spell no compound cerebration occurs if, as in James's case, there is no integration of auditory and visual patterns, but in learning to read compound cerebration must occur. Why was it not occurring?

James's eyesight was normal, but his eye-movements were poor. When tested with a reflection from a torch he tended to move his head where he should have moved his eyes, and this even horizontally, as well as vertically. His response when imitating finger movements was far too quick. It was accurate as regards the actual finger moved but very inaccurate as to time of the movements. This might be slower or quicker than my movement. (See p. 174).

There were many extra movements of other fingers, a sign of spreading area of action among the neurones of the brain, as were the extra movements in forehead, feet and shoulders, that had attracted my attention when I was originally watching the class.

James required special training in:

1. Eye-movements.

2. *Inhibition of the too rapid response* to stimulation, thus allowing the pause needed for the nerve impulses set up by stimuli to do their work among the dendrites, so that really definite patterns might be built up among the neurones. Only such definite patterns can react with one another in compound cerebration. James in his 'reading' failed to form definite patterns via visual stimulation from the words, partly owing to poor eye-movements, partly owing to lack of a pause as he looked at each word. He always made a wild guess, i.e. a responsive movement, directly he came to a word. His too rapid response decreased his intellectual ability in all directions. His class teacher's comment was 'James lacks concentration', but she had not analysed further in terms of his movements.

His eye-movements were greatly improved by special exercises.

He was given the imitative finger exercises (see p. 173) but told to count three to himself before imitating any movement.

Then a week later the proceedings were varied and I said I should bend my finger once, then straighten and bend again in exactly the same way. James was only to imitate me on the second occasion.

We did this in turn to each other, and scored successes in catching the other out, i.e. if he or I imitated the first bend instead of the second we lost marks. James did improve in his reading, but I only had him for ten minutes a day for a month, as he was then absent through illness for the rest of my time at his school. He needed much longer and more varied training, in the inhibition of responsive movements in all activities, including a workshop, presenting chances for attractive constructing which forced him to stop and think before he started to do. His home conditions were bad, he was allowed to run the streets and go to bed late and he was constantly a witness of 'rows' between semi-adult stepbrothers and sisters. He had probably been badly spoilt and thoroughly over-stimulated as an attractive baby and later neglected though not actually ill-treated.

The over-stimulation had encouraged but not controlled his spontaneity, which at seven, was manifesting itself as spreading area in his many extra movements, and in rapid wild guesses at words in reading lessons! Until he had learnt to inhibit his too quick responsive movements such spontaneity was unlikely to be brought under the directive control of the external stimulus (e.g. of a written word). Whether training at school could effect this while home conditions remained bad seemed doubtful. That the latter definitely retarded James's progress was very clear. His power of inhibition and consequent accuracy in imitation always improved from Monday to Friday and was definitely less again on Monday.

Effect of too little stimulation in the early years

A weakly infant left in a basement room in charge of a feeble grandmother while mother is out at work, would furnish an extreme instance.

There would be no one to play with the infant, e.g, to practise its eye-movements with some bright moving toy. If it is feeble physically it will not even have the movements of its own limbs, e.g. especially the hands, to watch. Nor can it see the moving objects in the streets.

When it is taken out it will be mostly to shop at night among crowds of flaring lights, stimuli then succeeding each other far too quickly and too intensely to produce effective co-ordination through eyes and ears.

Too little effective stimulation has often been the lot of very young children in big institutions. They lack the individual deliberate stimuli which a mother or nurse gives every day in the time she spares for play with the child. In nursery school, and kindergartens if the classes are overcrowded, the same danger exists, that the teacher may find it impossible to give the deliberate training, using play material, which is so much more necessary in these earliest years. So to arrange conditions that each child will really *pause* to allow time for stimuli to do their work among the dendrites is a very time-consuming process, impossible with large numbers.

Co-ordination defined

A child in a drill lesson exactly imitates the movement of the one in front of her. Here the stimulation of the retinæ sends nerve impulses to patterns in the cortex producing visual sensation. These patterns send on impulses via the pyramidal cells in cortex (see p. 60) to the motor cells of the spinal cord controlling that particular movement. There need be no interaction of patterns in the higher levels of the cortex corresponding to thoughts. The neuronic patterns are controlled in their co-ordination entirely by the particular visual stimulus.

Co-ordination involves only the adhesion of patterns in order guided by an external stimulus and is not so complex a process as compound cerebration. Patterns controlling reflex responses are examples of such co-ordination.

Co-ordination distinguished from compound cerebration

A child looking at a rose hip is told by the teacher that, 'It is oval'. Directed to describe the hip she says first, 'It is oval', then pauses, picks it up, holds it between finger and thumb lengthways and then in the middle. Looks at both diameters, measuring them by eye-movements, and says, 'It is twice as long as it is broad'.

In the first sentence, 'It is oval', the nerve impulses in her neurones were controlled and directed by stimuli from the teacher's heard words. Patterns of neurones were co-ordinated by those stimuli when she repeated the words 'It is oval'. No compound cerebration need have occurred.

But in the statement: 'It is twice as long as it is broad,' the directing and controlling stimuli, which come from the hip.

1. Activate old patterns built up by movements made in former measuring activities,
2. Produce new primary patterns for the length and breath of the hip through the child's eye and finger movements.
3. Compound cerebration occurs between all these patterns in the act of comparison, so that the difference between the two measurements is abstracted. This new temporary pattern controls the neurones which in turn control the vocalizing muscles for 'It is twice as long as it is broad'. Co-ordination involves only the passage of nerve impulses from neurone to neurone or from pattern to pattern in the same order that was followed when they were started by the original stimulus. Co-ordination may involve neurones in the cortex, or only in lower brain stem and spinal cord.

Compound cerebration means some variation in the original order of succession of nerve impulses from pattern to pattern and always includes interaction among neurones in the cerebral cortex.

We only know that such action has occurred when the patterns so built up, control the older structural patterns of brain stem and spinal cord and produce some variation in movements that we can observe, e.g. movements of vocal cords in speech, of the hand in writing or doing.

Compound cerebration contrasted with spreading area

In compound cerebration there is complicated interaction between neuronic patterns, most of which may have been already in existence before the arrival of the new stimulus. Nerve impulses reaching the brain through the senses 'may stimulate two or three groups of neurones which, after sending out nerve impulses, become quiescent and rest again. The groups thus secondarily stimulated may act in similar manner becoming quiet in their turn; thus there is not (as in spreading area), an ever-increasing amount of brain action but the first group (or pattern) interacts with the second, the second acts on the third and so on, so that finally an adapted action in movement or expression results.'[1] Such compound cerebration would occur if a child obeyed the order. 'Hold out your right hand at arm's-length in front of you, and bend your first finger ten times counting aloud.' (cp. p. 65.)

The reader can estimate roughly the number of already established patterns of neurones which interact in turn in a new pattern when the child responds to this auditory stimulus. This is not supposed to be a particularly useful exercise for a child, it is only mentioned to contrast brain action in compound cerebration with that in a simple act of co-ordination, like the imitative bending of a finger. Obviously in compound cerebration, there has been retentiveness of previous impressions, the patterns formed have been retained and can interact among themselves. When, in development compound cerebration and co-ordinated movements have produced speech, compound cerebration will become more and more frequent and be the physiological basis of thought or mental response.

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[1] Francis Warner in *The Nervous System of the Child*, p. 39.

Conditions to be fulfilled before Compound Cerebration can occur:

1. Primary neuronic patterns must be built up through the action of external stimuli co-ordinating already active neurones. These must be retained.

2. Primary patterns must be reactivated by new external stimulation which causes them to adhere either as wholes, or in part, to produce new secondary patterns.

This is the process of compound cerebration, the secondary patterns can control and express themselves in new movements. Such expression may be delayed.

Instances of delayed and immediate expression

A child may see a picture of a booby trap and by a process of compound cerebration detach it from its context in the story and attach it to a brother. But the child may not make the movements to play the trick on him for days. A teacher may ask a question, saying 'tell me the answer to-morrow'. An intelligent child has the necessary patterns stimulated into existence at once in his brain, but these do not control the movements to vocalize the answer, till they are re-stimulated next day by the sight of the teacher.

On the other hand, expression of the impression and its resultant compound cerebration, may be immediate. e.g. Child of two and a half puts his foot into his shoe, frowns, takes foot out. Pause. Puts hand in shoe and pulls out stone. Compound cerebration has occurred immediately producing a new movement.

With young children it is especially desirable to avoid the producing of secondary patterns at the moment when the aim is to build up the preceding primary patterns. e.g. The series of the numerals 'one, two, three' must be built up by clear, repeated, deliberate stimuli before it is used in measurement or counting.

Summary of characteristics of brain action

For purposes of description, the characteristics of brain action as they are revealed to the observer of children's movements and postures may be summarized under the headings of:—spontaneity, inhibition, impressionability, control through the senses, co-ordination, compound cerebration.

Spontaneity is basic for the development of all succeeding characteristics. At birth it is accompanied by some impressionability and a little later by control shewn in the temporary inhibition of spontaneous movements. Control leads on to action co-ordinated through the senses, and, with the advent of the power of speech, this becomes the basis of compound cerebration and mental development.

Some of these terms need a little further elucidation before the observations and descriptions suggested in the two Schedules (pp. 163 and 167) can be made.

Impressionability

Impressionability is early observed in cessation of spontaneous movements as when the baby's retinæ are stimulated by a bright light, or the ears by sudden sound. Later on, control of the neurones through impressionability to stimuli is shown in the turning of the head towards the source of the sound or by eye-movements in following a light.

'Later on still impressionability to the sound of the school bell in the playground is seen, together with varied co-ordinated action as some boys put their tops into their pockets and run into line. Others look up to see if the master is coming and then go on with their play; here the first impression is followed by action, while the second impression removes the stimulus of the first. . . . Some children simply stand still and do nothing when they hear the bell; the impression produces inhibition only. . . . One boy makes grimaces, stamps on the ground, throws down his top, picks it up again, drops it into his pocket and finally gets into line; impression by sound leads in him to extra movements with a spreading area of brain activity followed by co-ordinated action.'[1]

Impressionability means that nerve impulses resulting from external stimuli can cause changes in the neurones of the central nervous system, and, more especially the neurones of the higher levels of the brain, so that they enter into new relationships with one another. In other words, impressionability is the faculty, inherent in dendrites of responding by growth, movement, or some other change to the passage of nerve impulses at a synapse.

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[1] *The Nervous System of the Child*, p. 109. Francis Warner.

For example a child bends a finger in exact imitation of the teacher's movement. Light rays from the teacher's moving finger have stimulated nerve endings in that child's retinæ. Nerve impulses have then passed to some (relatively few) groups of neurones in his brain. If these are sufficiently mature and well nourished they will be impressionable, i.e. there will be interaction of their dendrites with dendrites of other groups, so that, after a short pause, nerve impulses can pass out to certain muscle fibres in the child's arm which contract and relax to allow his finger to bend.

Because the neurones are impressionable simple co-ordinated action among certain groups of neurones has resulted in simple co-ordinated movement.

If the neurones are not impressionable, they cannot be organized in patterns by stimulation, and the child is ineducable. The observer can judge by new movements or changes in response, whether stimuli are producing desirable changes among neurones of the brain.

Impressionability may be shewn then by movements in varying circumstances, e.g.

1. When new patterns are formed.
   e.g. Hand first moved towards bright keys or child learns to say 'boat' when seeing the word.
2. When old patterns are caused by a stimulus to react forming new patterns.
   e.g. When child compares 5 oz. with 3 oz. weight and says 'heavier'.
3. When patterns are controlled by a stimulus through the senses.

e.g. When a child imitates the bending of a finger.

Conditions necessary for Impressionability:

1. Maturation of sense organs, and of afferent, and central, neurones certainly.
2. Most physiologists would say that the *motor* neurones concerned in conducting impulses to the muscles to produce responses must also be mature enough to allow impulses to pass.

Years ago, William James said that: 'No impression . . . comes to us without occasioning a movement, even though the movement be no more than the accommodation of sense organs.' (e.g. eye-movements.) Some modern theory goes further and says that no impression is possible unless the whole reflex arc can function, that the degree of vividness of the mental process or impression is directly related to the degree of openness of the motor neurones to nerve impulses (for examples see chap. III, eye-movements, pp. 130 and 131).

3. The neurones concerned must be in a well-nourished condition, that is, able to produce free energy on the arrival of nerve impulses.
4. For maximum impressionability by a particular external stimulus neurones should have been recently co-stimulated.[1]

Changing rooms or definite physical exercises between lessons, besides improving circulation and posture, will ensure a good supply of nerve impulses from muscle sense organs. These impulses provide just the needed gentle co-stimulation of neurones.

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[1] This is difficult to prove experimentally, but seems to follow from Pavlov's work on conditioning and Kappers law of Neurobiotaxis. (Ch. I, p. 46.)

5. For good impressionability the stimulus (external change in the environment), must be of sufficient intensity, and of sufficient duration, or else be repeated frequently and rapidly enough.
6. On the other hand time must be allowed (the pause) for dendritic growth, or movement, or change of some kind to build up good neuronic patterns.

Some general considerations follow from the foregoing conditions for good impressionability.

Maturity of neurones

Stimuli must wait on the maturing of neurones before they can effect neuronic relations. Thus Gesell's experiments with identical twins have shown that both will climb a stair equally well, when a certain stage of neuronic maturity has arrived, although the one twin has been trained in the art for some weeks previously while the other has not.

Some of the last neurones to mature in the individual child are those last evolved in the human race, i.e. those associative neurones in the cortex whose patterning depends partly on speech movements and word meanings (chap. I, pp. 51 and 81).

Maturity comes long before this to neurones concerned with movements of limbs, hands, fingers, eyes, etc. That is why the most modern practices of nursery school and kindergarten depend on stimulation of ear, eye and of muscle sense, aiming to produce response movements with the minimum of verbal teaching.

Arnold Gesell in *Infant Behaviour*, 1934, describes some beautifully detailed observations of situations in the child's first year, showing that material, such as cubes, rings, rattles, bells, only stimulates to effective response when the neurones concerned have reached the appropriate stage of maturity. Is it quite certain that the work aiming at stimulation of certain mental processes, e.g. the number work of the upper classes in infant schools is always adapted to the stage of maturity of the child's neurones?

Early maturity of muscle sense organs

Much has been written concerning 'sense' training in the past but full advantage has not yet been taken of this fact of the early maturity of the neurones connected with the myriads of muscle sense organs.

At the stage when the neurones of the child in 'Nursery' or 'Infant' school are unready to respond to the stimuli of verbal arithmetic teaching, the neurones connected with the muscle sense organs can be organized into patterns by appropriate stimulation. Then, later on, when verbal stimulation becomes effective, these earlier formed patterns will be interrelated by the processes of compound cerebration and form a sound basis for arithmetical conceptions. The difficulties of older children in arithmetic are often due to failure in the building up of just these early neuronic patterns, dependent on carefully planned stimulation through muscle sense organs, at the appropriate developmental stage.

The head master of a certain 'Special Difficulty' School when he gets a boy or girl whose special difficulty is in arithmetic, finds that the child is often greatly helped by playing with bricks and material which

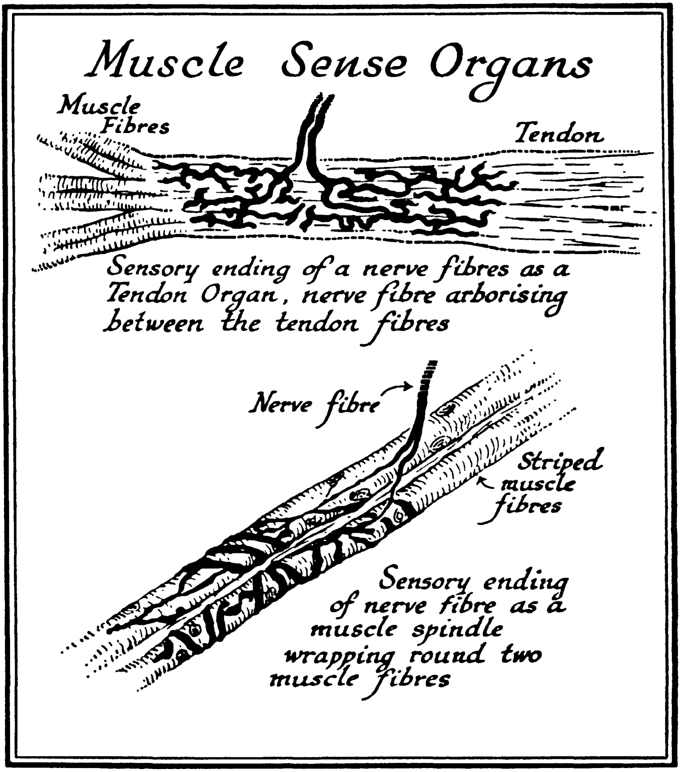
Muscle Sense Organs
Muscle Fibres
Tendon
Sensory ending of a nerve fibres as a Tendon Organ, nerve fibre arborising between the tendon fibres
Nerve fibre
Striped muscle fibres
Sensory ending of nerve fibre as a muscle spindle wrapping round two muscle fibres

DIAGRAM VIII (*magnified*)

it had never had at the appropriate age for this material.

Large classes make such work difficult. Some suggestions are given (see p. 66, etc.), but practical teachers will easily devise far better methods once they realize the important part in later development played by muscle sense organs if rightly stimulated in these early stages.

Two varieties of muscle sense are used in early education, as a means of inducing among neurones, relationships that will form a valuable basis for later mental processes. These two varieties are:

1. Muscle Sense in Tension.
2. Muscle Sense in Movement.

Muscle Sense in Tension:

The strain produced by a pull on a muscle is 'felt' by neurones in the brain. Place a weight on the end of a child's outstretched hand, and the pull on the muscles of the arm and back is 'felt' by cortical neurones in the brain. When the degree of such a muscle tension is to be thus registered in some cortical pattern, the hand should be held out freely, unsupported, it should be moved gently up and down, so that the stimuli through gravity may be effective, the fingers should be open, so that shape and size shall not be experienced at the same time. Thus only one impression,[1] that of weight, will be clearly impressed and a good neuronic pattern built up.

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[1] A good way to obtain such clear single impressions of weight (the pull of gravity) is to make use of pillboxes obtained from a chemist. These can be lidded, all of the same size suitable to stand on the child's outstretched fingers and made up with shot imbedded in plasticine to any desired weight. A number of boxes weighing 1 oz. each, and other sets of 1, 2, 4, 8 oz. respectively, and others of 1, 2, 3, 4, 5 oz. are needed for different ages and for giving, through muscle sense, basic impressions of ratio, fractions, etc.

Weighted pillboxes and muscle sense in tension used to produce the patterns needed for a later comprehension of a standard of weights

In using such apparatus, verbal guidance is cut down to the minimum. A few terms needed by the child to give expression to his impression (what he 'feels'), are best taught previously, if not already known, as words without meaning. These words too are learnt partly through muscle sense (in movements of the lips), by the child's imitation of the teacher's lip movements. Sight of the teacher's lips and hearing of her voice also play their part.

A five year old might learn in play such terms as weigh, same, heavy, light, an older child should know names of numerals in order one, two, three, etc., add, equal, two times, half. Give the impressions of the weights as described above with the appropriate pillboxes, first with no descriptive words, merely saying 'feel' letting the child imitate your movement as you balance a box on the end of the fingers of your open hand. Then give the impression again, coupling with the already familiar word. e.g. Saying to a five year old: 'Let's weigh,' put a 1 oz. box on the tips of your own four fingers, and then on his. Repeat with another 1 oz. box and let him say: 'Same weight' after you. Repeat with two more similar 1 oz. boxes several times.

Next day perhaps 2 oz. boxes on each hand may be used. Another time a 1 oz. box on one hand, a 3 oz. box on the other hand will give a 'surprise' impression and can be coupled with 'lighter', 'heavier'. With such young children only a very few minutes per day would be spent on such formal training and all by way of play. An older child, with a number of 1 oz. boxes may be guided, by balancing them successively on his hands to find out, 'they are all of the same weight', and then may be told that each weight is called 'one ounce'.

Next day he may be told to shut his eyes, one 1 oz. weight is placed on finger tips of his right hand and he is asked: 'What weight?' Then a second 2 oz. box replaces the 1 oz. and he is told 'two ounces', and so on. Then the series is repeated, placing the weights on the left hand, while he himself says: 'one ounce'—'two ounces'—'three ounces', as he feels the additions. Next he opens his eyes and is directed. 'Now add one ounce weight to your own hand.' 'Now add another ounce weight,' and so on. He then gets a real impression through muscle sense in tension for 'addition' as well as for 'weight' and for 'ounce'. When he himself adds ounces to his hand he gets impressions through muscle sense in movement.

The series of 1, 2, 4, 8 oz. weights can be used later on to give impressions of proportion long before any purely verbal symbolic meaning can be understood. Boys and girls of six to seven, enjoy discriminating between $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ oz. weights or the still more difficult task of distinguishing $3\frac{1}{2}$ ozs. balanced on one palm from $3\frac{1}{4}$ oz. say on the other.

Children can work in pairs with sets of such boxes if the respective weights are marked on the under side of each box, and many variations and tests occur to them. e.g. Two pillboxes, each ½ oz. weight are placed on one palm, one box of 1 oz. weight on the other. The unwary 'guesser' who is not attending to his muscle sense impressions, calls the two boxes heavier, to the great delight of the 'teacher' child. Both learn a good deal about addition, subtraction and fractions.

Muscle Sense in Movement:

It is less easy to control the *degree* of impression produced through muscle sense in movement than that produced as above by muscle sense in tension, but this sense is also used very early to give impressions and build up neuronic patterns, e.g. the meaning of such a statement that 2 is greater than 1, 3 than 2 and so on is understood by moving an arm once, then twice, then three times, etc.

In counting (see earlier examples in this chapter for use in 'counting' lessons), objects may be equally spaced, the child counts by looking at them and his eye-movements mean that impulses from the sense organs in the contracting muscles moving his eyeballs produce basic impressions of increasing numbers. If he is next told to move a finger and arm to point at each object in turn, impulses from sense organs in the muscles moving the arm reinforce the impulses from the eyeball muscles.

When the time comes to use a standard length in measurement, use should be made of movements of the hand and eyes (see p. 130).

Muscle sense in movement used to build up a pattern for a standard of length, the inch. (See p. 74 for 'feet'.)

The child can have sticks 1 inch, 2 inches, 3, 4, 5 inches long, he must look at each in turn, from end to end, then feel the length with a finger passed slowly from end to end, first with eyes shut, then with eyes open. Lastly each length can be expressed by the number and the name 'inch', previously learnt.

Neuronic patterns needed for the understanding of proportion.

These can be made, by estimating at sight and by finger movements the proportionate lengths of sides of rectangular cards with one side twice or four times the other. The child moves his eyes in looking along the top from corner to corner and then downwards from top to bottom corner, receiving in each case a different degree of impression.

The order of procedure in the above examples would be:

1. Teach names of numerals in order.
2. Establish a set of impressions of weights by pill-boxes.
3. Employ the numerals to express these impressions when revived.
4. Establish a set of impressions for lengths by eye and finger movements separately and then together.
5. Express these impressions by use of numerals.

Such fixed and accurate relationships among the neurones will be easily revived and integrated in new and more complicated patterns later on, facilitating the understanding of comparison and proportion, and the appreciation and naming of ratios.

All sorts of work, with special bricks and weights, in measuring of water and sand, will, at this time, be used to give the child impressions of 'quantity' of varying kinds.

Using muscle sense in movement in teaching tables

e.g. In Twice times table: Teacher says 'Do as I do', then counts, swinging an arm, and says '1, 2, 3, 4, equals four times'; swinging an arm, and says '1, 2, 3, 4, 5, 6, 7, 8, equals eight times'; '8 times equals twice four times.'

Here the pattern made by the 8 movements with its degree due to stimulation of the muscle sense organs is coupled with the pattern formed through the auditory stimulus of the sound 'eight'. Its degree will be *felt* to be twice that of four. A new permanent pattern is built up by repetition of the movements together with the auditory stimulus in which:

'8 times equals twice four times'

becomes the *expression* of the *felt* relationship. Building up the whole table in this way gives many patterns from which later on the idea of ratio is abstracted, because this felt relationship is the common factor in all of them, and presumably has definite representation in the neuronic structure of each pattern.

Sometimes, though the importance of 'apparatus' in number work is understood, the importance of the child's *own movements* in the use of the apparatus seems insufficiently realized. Guided stimulation of muscle sense organs, by the right use of apparatus, is essential for the building up of good patterns among the neurones to ensure clear conceptions of arithmetical relationships. The mechanism explained under 'Grasp Reflex' (chap. I, p. 39 *et seq.*) partly explains why.

Eye-movements used to build basic neuronic patterns in other subjects

1. *In geometry or woodwork*, 'vertical'—'horizontal'—'sloping', are terms (sounds), which should have their meanings based on impressions produced by the appropriate eye-movements. Such impressions will be more permanent than merely verbal definitions.

2. *In drawing*, a child must get an impression of the length of a line representing the height of an object and then of another representing its width. He will only do this accurately and express the impression satisfactorily if his eye movements are good, so that the muscle sense organs concerned are stimulated to the right degree.

3. Points of the compass as represented on the map should be associated with appropriate eye-movements in the four directions.

Such illustrations indicate the value of good eye-movements not only because they conduce to accurate seeing but because of the many basic impressions obtainable through the sense organs in the muscles moving the eyeballs (chap. III, p. 129).

In geography the child can be reminded of his feelings when walking five miles, and so get from muscle sense an impression which will give him an idea as to the distance from London say to Aberdeen.

Early impressionability of the brain through muscle sense organs is probably due to prenatal conditions. The child, before birth, lies in a uniformly warm dark environment, sometimes completely surrounded by fluid, sometimes pressed against the wall of the uterus, so changes in pressure and tactile stimuli, together with the child's own movements are the chief educators of his neurones, and this must be accomplished mainly through the sense organs in the muscles. Hence their early maturation, fulfilling the first condition for impressionability.

High threshold of impressionability through eye or ear in the young child.

Normally the threshold of impressionability through eye or ear is higher the younger the child. This partly explains why it may be necessary to repeat an oral stimulus rather rapidly, e.g. a younger child may need a direction or summons repeated three times, while an older child will respond to the first call, if he has been trained to do so. Controllability through the senses is greater in the latter case.

Possibly this higher threshold for impressionability, partly accounts for the fact that, the younger the child the more desirable it is to stimulate only one sense at a time to produce impression and control, e.g. when young children are looking at a picture the minimum of words is used. The picture is described first, and then exhibited for some minutes in silence.

This method of one sense stimulation is also desirable, because the younger the child the greater will be the tendency to reversion to the infantile spreading area among the neurones.

As already stated the threshold of impressionability will be lower for one child for stimuli received via the eye, for another for stimuli via the ear, and advantage must be taken of this in the making of the early impression. This is perhaps most necessary in speech training where some children learn more readily via stimulation of the retinæ, in imitation of movements of the teacher's lips. This would especially apply to the slightly deaf.

Controllability

Controllability like Impressionability is shown in all cases where some external stimulus results in movement or some change in movement, e.g.:

Reflex movements, as when the infant turns its head away as the cleansing swab is brought near the nostril.

Arrest of the infant's spontaneous movements by some sight or sound. This is very temporary control.

The later movements of the baby's hand towards the bright object. Here the stimulus controls a response movement of a new kind. The reflex movement in (1) involved much less complex patterns.

Imitated movements of all kinds. These may be the result of simple co-ordination of neuronic patterns controlled by light stimuli from the movements imitated.

Movements which are the outcome of both co-ordination and compound cerebration, e.g. movements in the use of tools (pencils, brushes, plasticine, etc.).

Spreading area of brain action

The antithesis of controllability is seen in extra movements, at their worst in chorea, and in the movements of uncontrolled emotion, whether of joy, grief or rage.

Such movements are due to a spreading area of brain action. An increasing number of neuronic patterns are in activity *at the same time* producing simultaneous incoordinated movements in various parts of the body. This contrasts with the controllability shown in compound cerebration. Here nerve impulses, the result of past or present stimulation, bring neuronic patterns into *successive* activity, the earlier activated neurones *resting again* as the nerve impulses pass on to other neurones, e.g. this process happens when a child is telling what it (*a*) saw, (*b*) heard yesterday, or when a child carries out a series of acts of comparison.

Perhaps sufficient examples have now been given to illustrate what is meant by the characteristics of brain action and how they must be taken into account. *Spontaneity:* shewn in the earliest movements, and still frequently so manifested during the years of childhood gradually becoming transformed in the adult to spontaneous thoughts. *Impressionability* is shewn when a sense organ has been stimulated and spontaneous movements are thereby arrested or reflex movements are altered; this results in *Controllability* of the neurones through the senses becoming obvious to the observer in *Co-ordinated* response movements, and later in co-ordinated thoughts, such as reproduction of the numerals in their order. This indicates that the neurones are acting together in a certain order under the control of the order in which the original impressions were made. If these impressions are retained as patterns among neurones in the cortex of the brain, then, on some new stimulation, there occurs *Compound Cerebration* in which patterns become reactive and interact with one another in new ways as in acts of comparison and choice.

It is at this stage that language plays so large a part in aiding the process of abstraction from primary patterns and in producing varied mental activities.

For reporting on a school child a schedule embodying the above characteristics is needed. This is given in Chapter V. Chapters III and IV give suggestions as to the movements and postures to be observed before the characteristics of a particular brain's activity can be described.

CHAPTER III

SOME TYPES OF MOVEMENT WHICH MAY BE OBSERVED AS SIGNS OF NEURONIC ACTIVITY

Movements are to be considered in this chapter as signs of the way in which neurones are functioning, with special reference to those, in the brain, on which mental processes depend. The movement of any part, large or small, e.g. arm or eye, depends on nerve impulses to the muscles which control the part, coming from a definite group or 'pattern' of neurones and this fact is the basis of much that is important in child management and education.

Movements of small parts of special importance

To the educational observer movements of limbs and large parts of the body are of less importance than the movements of such small parts as the eyes, the fingers, the muscles in forehead and round the mouth, for the neurones concerned in the fine movements of these smaller parts are much more intimately connected structurally and functionally with those more recently evolved patterns of neurones concerned with mental processes.

This intimate connection is recognized in educational practice in the stress laid on eye and hand work as a preparation for mental work quite apart from its value in the satisfaction of the desire to create. By such cultivation of fine, independent, and co-ordinated movements of hands, fingers and eyes, training is given to groups of neurones which later form part of more extensive patterns concerned with mental operations.

In the observation and description of movements in these small parts, it is important to note, as well as the actual parts moved, the *sequence* of movement, its *rate*, and its *quantity*, remembering that only accuracy of this kind will make it possible to deduce from the movements whether the neurones concerned are functioning well or ill.

In Chapter VI, page 174, is given the description of some imitative exercises, which will illustrate what is meant here by sequence, rate and quantity of movement.

Some types of movement

1. Spontaneous Movements:

Apparently uncontrolled by an external stimulus.

Desirable: Flinging arms about, jumping, shouting, when first rushing out to play from the classroom before the children settle down to play with tops, balls, or each other.

Undesirable: e.g. uncontrolled movements of eyes, twitches of fingers, many fidgety movements of hands, head, shoulders, feet.

2. Response Movements:

Obviously following and controlled by some external stimulus, generally resulting in control by the child of some part of his environment. e.g. Eye-movements as eyes follow a line of figures on the blackboard, finger movements partly controlled by sight and controlling a pen in writing, movements of limbs in drill, running movements when the child responds to a call, reflex movements as when an object threatens to touch the child's eye.

3. A Spreading area of Movement:

Here a number of movements spread from one part to another, often contiguous, and continue concurrently, while none of them are being *controlled* by external stimulation. Examples of such movements culminating either in a burst of laughter or in howls of rage are described on p. 127.

In the following examples there is a spreading area of movement accompanying other movements, which are being controlled through the senses, e.g. the tongue may be protruded while the child is writing, the head dropped to one side and fingers fidgeted while he is questioned. He may bend the knees continually while standing to read aloud.

Desirable spontaneous movements

must now be considered in more detail in their earlier stages, if their later manifestations in a child of school age are to be understood (see also pp. 34—36).

In the Infant: As seen in the infant soon after birth they are slow movements of separate parts of the body, limbs, fingers, toes, eyes. If the eyelid of the sleeping infant be gently raised, spontaneous, incoordinate, movements of the eyes will often be seen.

'Lalling' sounds uttered about the age of two months, independently of external stimulation and without any 'attention' by the infant are also produced by spontaneous movements of the throat and tongue. All these early movements are independent of external stimulation of the sense organs, do not occur in any definite series, or in any particular order, are exceptionally marked at this earliest stage of life and are proportional to the circulation. If this is deficient spontaneous movement is reduced.

What do spontaneous movements indicate about the infant brain?

Such movements may be taken as signs (1) that the infant is well nourished, and (2) that impulses are passing from small groups of relatively few neurones to the groups of muscles controlling the movements of single fingers, toes, etc. First one such group or pattern sends out impulses and then ceases its activity while another begins. Such activity indicates that these small groups of neurones are at such a stage of maturity that they will shortly be able to form functional unions with other neurones and so build up larger patterns to control co-ordinated movements.

Part played by external stimulation:

These functional unions will come into being after external stimulation by sight or sound has sent impulses, via the sense organs, to the already spontaneously active neurones (pp. 45, 58 and 62).

External stimulation leads to the direction and control of spontaneous movements, and, Dewey's dictum concerning later stages holds even at this early stage: 'The child is intensely active and the question of education is the question of taking hold of his activities, of giving them direction.'

Dr. Charlotte Bühler's description of spontaneous movements:

Charlotte Bühler in *The First Year of Life* calls the random, spontaneous, movements of limbs, fingers and toes, 'impulsive movements' and describes them (p. 74) as 'purposeless' movements receiving no attention from the child, 'they are individual separate movements of all the limbs, the direct outlet of an unfolding pressing activity with which the living being is born'.

While commenting on the difficulty of accurate description of these undirected movements, C. Bühler gives examples such as the following (p. 77):

Boy, thirteen days old, his 'hands are slightly balled, arms a little bent travel about in the air, one goes away from the chin, the other at the same time hits the chin.'

'All the fingers move, first three fingers of the right hand are curled in, the other two at the same time are stretched towards the back of the hand. The fingers of the left hand flutter aimlessly without any sort of plan, each moves for itself, to and fro in its own tempo.'

C. Bühler goes on to state that these 'impulsive' movements 'disappear proportionately in that degree in which his attentive activity with the child's own body or playthings begins, but they keep their existence in a form of floundering and careless playful movements which are to be found even in grown-ups'.

Experimenting Movements develop from spontaneous movements.

She describes (p. 75) how a wandering glance, beginning spontaneously without external stimulus, travels here and there till it meets with some stimulating object and then: 'A lively activity unfolds itself different from those reactions which result only from a stimulus.' In contradistinction earlier in the book she has described how the very young infant, supine on the nurse's lap, reflexly turns aside the head as a swab is brought near to clean the nostril. Attentive activity differs from this in that it depends as described above on coincidence of external stimulus with spontaneous action among the neurones. Interaction results among the dendrites of the neurones and leads to further attentive experimenting with the child's own body; hands and arms are moved, the head is lifted, the body arched. Such, no longer random, movements lead up to the co-ordinated movements involved in sitting, creeping, crawling, walking, standing.

(For detailed description of these developments, C. Bühler's *The First Year of Life*, and Arnold Gesell's *Infant Behaviour*, 1934, should be consulted.)

Persistence of spontaneous movement in the school child:

Although they are thus gradually replaced by experimenting movements, spontaneous movement recurs again and again in the growing child, e.g. in the aimless, happy, shouting, skipping, jumping of children let out to play from the controlled conditions of the classroom. Some of the neurones momentarily revert to the infantile way of working. Then the children settle down again to movements co-ordinated and directed by stimuli from, ball, marbles, tops, or from each other as in 'tag'.

Again, desirable spontaneity is seen in the child of kindergarten age in changed expression, in smiling about the mouth apparently of self-contained origin not stimulated by what he sees or hears, in somewhat incoherent chattering and disjointed utterances. The eyes may turn to either side without being directed to any particular object, the hands may show much spontaneity of the fingers as they hang by the side, the feet may be shifted, the shoulders shrugged. All such spontaneous movements represent activity in the neurones, desirable as long as it is really controllable through the senses or by neuronic patterns already acquired. It then represents a further supply of neurones shortly to become capable of co-ordination for organized thought.

Result of lack of spontaneous movement in infancy:

Lack of the normal spontaneous movements is a bad sign at any age, but it is serious in the first few weeks. Hazlitt[1] refers to the case of a child, who, at eight years of age, lacked capacities, through illness lasting from two weeks old for several months, as a result of which spontaneous movements were then almost nil. This importance of spontaneous movements in the first months, for later neuronic development, makes it imperative to prevent malnutrition then, one among many reasons for the stress which should be laid in Mothercraft classes, as well as at Welfare Centres, on the desirability of breast feeding, together with every sort of ante and post natal care.

Malnutrition, leading to lessening of the normal spontaneous or random movements in the early months, means that environmental stimuli have too little raw material out of which to fashion neuronic patterns for integrated movements, at the time when neuronic growth is greatest.

A child so handicapped, may, at 7-8 years of age, display many hesitating clumsy movements, or else 'nervy' twitchings, showing poor co-ordination and indicating an infantile condition of neurones.

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[1] Hazlitt in *Psychology of Infancy*, p. 43.

Undesirable spontaneous movements

Chorea, a reversion to infantile spontaneity.

Malnutrition at later stages, particularly in the case of children of the 'nervous' type, may lead to a rapid fall in weight, the child dropping one or two pounds a week even though the face may remain fairly full, and there is no disease, or failure in appetite. Such a child is apt to become more infantile and overmobile, many of the neurones reverting to an incoordinate spontaneous mode of action, but also exhibiting repeated series of movements. Twitching seen in face and fingers may then pass into the movements of Chorea ('St. Vitus's dance').

These movements cannot be controlled, indeed speaking to the child, or other external stimulation merely tends to increase them, in this uncontrollability they differ from desirable spontaneous movements.

Short of the movements of actual chorea, spontaneous opening of a child's hand will often cause dropping of articles and then he may be unjustly blamed either for a disturbing noise in the classroom, or for carelessness in losing property.

Temporary reversion to infantile spontaneity due to fatigue or hunger.

A merely temporary reversion to infantile spontaneity of movement, also due to nutritional causes is seen in the uncontrollable excessive fidgety movements of children of all ages when cooped up in close rooms, when wanting food, or when tired. Any stimulus received then, tends to cause impulses to spread out fortuitously to any muscle in the early random way, fingers twitch while holding the pen, eyes move irregularly mainly in the horizontal direction, feet are shuffled, and the child is considered thoroughly cross and irritable!

Such movements are signals to the observer to remove the conditions producing them.

Uncontrollable irregular eye-movements are another undesirable form of spontaneous movement dealt with more fully at the end of this chapter. These again often cause the child to be unjustly blamed for inaccuracy and carelessness.

'Inattention' causes fidgety movements:

Speaking generally, fidgety movements are often blamed as causes of inattention, whereas actually the so-called inattention may be the cause of the fidgets. External stimuli for one reason or another fail to produce that imperceptible pause which allows coordination of the spontaneous impulses arising in the neurones. So instead of orderly movements or orderly thoughts, spontaneous movements or disconnected thoughts occur. Fresh air and sun, or food, or rest, or sleep, or just return to full spontaneity of action, as in the playground, may be needed to restore to the neurones the power, temporarily lost, of responding correctly to stimulation through eye or ear.

Value of the inhibitory pause before response:

Correct response includes the preliminary inhibition of all overt response, that pause which allows full time for the physiological dendritic changes that the external stimulus can effect when desirable spontaneous activity is occurring among the neurones.[1]

Overaction of frontal muscles:

Still another undesirable movement, spontaneous in nature, is seen when the frontal muscles overact. It is often accompanied by rather vacant 'staring', such as is normally characteristic of an infant during the short wakeful periods of the first month. Such an expression in a child of school age suggests untrained neurones, and energy running to waste. If handwork, exercises, or games, lead to the disappearance of such overaction then the neurones are being successfully stimulated to a less infantile functioning. Staring and overaction of frontal muscles as well as clumsy, jerky, disconnected movements are sometimes seen in mental defectives, signs of the persistent infantile spontaneous functioning of neurones. But mental defect is often accompanied by a lack of the normal spontaneous movements in the child's earlier years.

Spontaneity in movement controllable through the senses should be seen in children of all ages.

Spontaneous thoughts

The same kind of activity among groups of relatively few neurones forming relatively simple patterns, must be the physiological basis of the spontaneous thinking, disconnected and often imaginative, which characterizes a young child's mental processes. During the pauses of quiet attention, following some stimulation via eye or ear, the trains of nerve impulses set up cause these spontaneously active neurones to become functionally connected and 'trains of thought' result, in similar fashion to the trains of co-ordinated movements (e.g. in eating, walking and running) which gradually resulted from external stimulation during early spontaneous movements.

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[1] For a most important interpretation of the value of the inhibitory pause in our education, see F. M. Alexander in *The Use of the Self*, 6s.

Spontaneity in thought replaces spontaneity in movement.

In the adult spontaneity in thought progressively replaces spontaneity in movement and the continuance of mental development will depend on such a residue of spontaneity, combined with the possibility of further dendritic growth. Probably the physiological basis of spontaneity in movement and thought is inherited by the individual, and training can only help to develop what is already given at conception, but poor nutrition, lack of training, or bad training, may allow native spontaneity to be wasted or undeveloped.

'Never stop a child's movements unless you know why you stop them,'[1] is one maxim which follows from a belief in the importance of spontaneous movements. Equally true is it, that too great spontaneity in thought, imagination, fantasyings, uncontrolled and undirected by stimuli from the real environment, will be as bad for the child as the spontaneity of chorea in the realm of movement. Spontaneous movements and spontaneous thoughts must be controlled and directed but not repressed, serving as the raw material, from which, by provision of suitable stimuli at the proper stages, orderly movements and orderly thoughts are made possible.

So the child comes to control that external world which must first control him.

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[1] Dr. F. Warner in *Study of Children*, p. 42.

Response movements[1]

These make up the greater part of the child's behaviour, but will be very briefly dealt with here as they are extensively described by physiologists, psychologists, and specialists concerned with special types of response movements, e.g. physical exercises, eurhythmics, writing movements, movements concerned in speech and handicrafts.

In the classroom, the child's neurones are largely controlled by stimuli reaching them via the ear or the eye. Some children's neurones are activated more easily via the eye, others via the ear. In drill, the child, who is most easily controlled via the eye, will be seen to look at other children before responding to some word of command. Such a child will probably come more readily when beckoned than when called, the sound of a command may even cause a number of irregular movements, (spreading area), whereas a gesture is quickly followed by accurate and good response. This kind of observation of individual response will often help to suggest the best method for controlling the 'difficult' child.

Prompt or delayed response—Inaccuracy in time or degree of response.

When an oral command is to be obeyed, or any movement has to be imitated, the child's response may be prompt or delayed, there may be inaccuracy in the time or in the degree of the response, the inaccuracy may occur only when imitation is attempted in such small parts as the fingers, or may also be observed in larger parts such as the limbs. These inaccuracies may occur symmetrically or may be more obvious on the right or left side, they may coincide with fatigue, hunger, constipation, stuffy atmosphere, etc., but they may be characteristic of a particular child even under the best physical conditions, although no defect of eye or ear is present. They may be the unrecognised cause of much failure, i.e. "clumsiness."

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[1] For the early genesis of Response Movements consult *The First Year of Life*, Charlotte Buhler; *Infant Behaviour*, 1934, Arnold Gesell; *Animal Drive*, Prof. E. Holt. For an illuminating new light on the need and possibility of 'conscious control' of response see *The Use of the Self*, by F. M. Alexander.

Cause of inaccurate response:

Obviously the inaccuracy may be due either to (1) ineffective stimulation of neurones on the sensory side, e.g. to a faulty sight impression say, or to (2) some defect on the motor side in the neurones producing the response movement. If the child's thought processes display similar inaccuracies, then training of his neurones to produce accurate movements, in response to stimulation, will also help his mental development. (See chap. VI, p. 170, for some ideas as to such training.)

Necessity for some delay before response:

A certain delay in response is often necessary to give time for the impulses generated by the stimulus to have their full effect on the neurones concerned in co-ordinating the response movement (see pp. 49, 60, 65 and 88). Too long delay may be due to the inherited constitution of the child's neurones or to some slightly abnormal gland condition affecting muscle tonus but it may also be due to lack of training.

Value of games in training rapid response: Games such as hockey, where the child gets hit if it is too slow, may help, or graduated exercises with balls, shuttlecocks, dabbing at moving dots, noting meaning of a picture seen for a few seconds, as in 'Snap', etc.

All exhortations to 'be quick', or conscious competition with quicker children is to be avoided as leading to 'spreading' area of action among the neurones (see pp. 93 and 111) and so to confusion and inaccuracy of thought or movement. The incentive should be solely the amusement of the game or the skill to be acquired. Rapidity of response is often best trained in 'games' rather than in formal lessons. In any case correct thought processes are of much greater value than rapidity.

Over rapid response:

Response must be considered over rapid when it leads to inaccuracy, whether in movement or thought, and the measures taken to produce accuracy will best ensure the necessary pause before the desired response. In such cases it may be desirable to stimulate only one sense organ at a time, e.g. if a child moves an arm too quickly in imitation of the teacher, and, as a consequence, is inaccurate as regards the rapidity of the movement, the teacher should not SAY 'too quick,' but should first repeat the movement with such exaggerated slowness, that the child must notice the time. When this has been accurately imitated the teacher can then proceed to the original tempo. Spreading area and confusion are thereby avoided, a condition which easily occurs in the 'overquick' child, if both eye and ear are stimulated at once.

A spreading series of movements
(See p. 115 for examples.)

A spreading series of movements is caused by a spreading area of action among the neurones, one group sends out impulses and continues to do so, not resting, after other, usually contiguous, groups have been brought into action. A smile may spread in the face following some spontaneous thought; this may pass on to widening of the mouth, half closure of the eyes, turning of head, and movements of the hands and fingers, till, in a burst of laughter, the whole body seems to take part. Similarly an outburst of rage means nerve impulses becoming reinforced as they pass from neurone to neurone over a widening area of the brain and finally out to muscles which produce the observed movements of rage. These movements will be antithetical to those of laughter. The reader might here recall, if he can, the spread of movements in a child's brow, mouth and hands precedent to an outburst of rage. Such forms of neuronic action are not compatible with intellectual work and will tend to remove any precedent train of thought. Laughter may be very useful. For example if a child or a class has become worried over some problem that the scholarship examination sets as suitable for a child of ten, a hearty laugh may dispel the unhelpful line of worried thought and leave the neurones free to be stimulated to a more useful process.

Movements of joy the antithesis of those of rage:

Again if movements of laughter can be induced in a child in the first stage of anger, by imitation either of the teacher or of other children, the threatened outburst of rage may be averted, for, though the movements of joy are the antithesis of the movements of sorrow and rage, they are akin, in that both are signs of spreading area of action among the neurones. The expression 'I didn't know whether to laugh or cry', illustrates the fact of this common basis.

Spreading area in movement and in mental confusion:

Emotion is frequently expressed in movements due to such spreading area and is usually accompanied by excitement and more or less mental confusion. Naturally if long continued, fatigue results, since so many neuronic patterns are active at the same time. Signs of such useless overaction among the neurones, often indicating mental confusion, are, protrusion of the tongue, inclination of the head to one side, fidgety fingers, during response to any stimulation such as a question. Direct notice of the useless movements only aggravates the spreading area, but the mental confusion of which they are the sign requires investigation!

Stammering.

Stammering indicates a spreading area of action among the neurones: 'here the spasm, accompanying and causing the defect of speech may be seen to commence in the muscles of the face about the angles of the mouth, in depression of the lower jaw, or in knitting of the eyebrows. The spasms usually commence and spread in the same order in the same child. On the first indication of visible spasm, which usually precedes the sound of the stammer, the child should be stopped in his effort to speak'[1]

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[1] From Francis Warner, *Study of Children*, p. 95. See also *Use of the Self*, F. M. Alexander, Chapter IV.

Every prolonged attack leads to its recurrence, hence the teacher must learn to observe the first signs of commencing spasm in the particular child. Singing, general physical exercises, and training in proper breathing, may help.

Eye-movements

The movements of the eyeballs are effected by small muscles attached to the globes of the eyes and arising from the wall of the orbit. These small muscles are supplied by three different pairs of nerves. When a small object is held about two to three feet in front of the face and moved from side to side and up and down, light from it stimulates the retinae and nerve impulses pass to neurones in the cortex and finally to the nerves, leading to co-ordination of these small muscles attached to the eyeballs so that the two eyes follow the moving object. When one eye turns to the right so should the other, when one turns upwards both should turn equally.

Fixation.

In looking at a stationary object some ten inches from the face the eyes turn slightly, but equally, towards one another. If they are steadily directed towards the object we say that fixation is good. Good fixation ensures that the image of the object falls on the 'yellow spot' of the retina of each eye, i.e. on the spot where stimulation by light rays from any object is most effective in sending in nerve impulses to the brain.

Muscle sense in eye-movements and judgment of distances and size.

Distances are unconsciously judged partly by the amount of muscular effort required for any eye-movements involved. The contraction of the muscles stimulates their sense organs, so that nerve impulses return from them to certain neurones in the brain, so giving information as to the muscular effort involved. A remarkable instance of this was noted during experiments in Berlin in 1925. These demonstrated that the apparent size of the moon varied for an observer with the amount of effort necessary to overcome the divergence of the eyes when the head was raised. Here then the motor impulses to the neck muscles as well as to those moving the eyeballs must have been a factor in this percept. But, as H. S. Langfeldt emphasizes, the resulting percept was a visual one of the size of the moon not a percept of eye muscle strain or of twisted neck. The resultant 'thought' as to the size of the moon was shown to be partly dependent on the amount of contraction in certain muscles of neck and eyeballs, i.e. dependent on the amount of stimulation of certain muscle sense organs.

One or two further quotations will illustrate the importance of eye-movements for mental processes.

'The will to perform movements of the eyes, or the innervation to the act is itself the space sensation' (Mack Trd., 1914).

'Visual phenomena are entirely motor.' 'There is no visual consciousness before the infant has made bodily responses to visual stimuli' (Dr. R. Nuel in *La Vision*). Dr. L. Grunhut emphasizes that we perceive form by running the eyes over the given object. The eyes are not just opened to receive possible sensations but perceptions are created when the eyes are allowed to wander over the object. The picture on the retina and the afferent impulse are not yet a perception, only by means of the *motor* response are the discrete points in space formed into a co-ordinated whole.

Compare with this Professor S. Alexander, in *Art and the Material:* 'Older writers used to say that afferent nerves conveyed sensations to the brain and mind, awakening there pictures, which represented external things, upon which pictures we then behave appropriately. These pictures are mythology. . . . What the afferent nerves convey to the brain is nervous (or mental) excitement. It is the efferent or motor reaction (always in their continuity with the afferent process) in which these excitements discharge, in virtue of which we apprehend the qualities of external things.'

In all these quotations stress is laid on the importance for consciousness of motor response to any stimulus, but, more particularly, of motor response by muscles moving the eyes and head, to stimulation of the retina. Such motor response means activity of all those muscles of the eyeball and eye concerned with producing clear vision. Kinæsthesis, or sensations of muscle strain, will play a part in any resulting judgments of size or distance.

Consciousness is dependent upon activity in the complete nervous arc:

The writers quoted above are not only referring to percepts due to muscle strain, but to some more subtle factor which makes consciousness dependent upon activity in the complete nervous arc, dependent on nervous impulses passing, not only from afferent to central neurones, but actually out via the motor neurones to the muscles.

The complete nervous arc is involved, as much in a percept of a wavy line, say, as in a percept of muscle strain:

H. S. Langfeldt[1] distinguishes between a percept of kinæsthesis localized in one's organism, i.e. a percept of the amount of muscle effort involved in any movement, and a percept say, of a wavy line or an upright column. The difference in the kinæsthetic experience of the wavy or upright line underlies the percept in each case but the percept is not itself of a kinæsthetic experience, any more than perception of movements in one's vocal cords, as one says the words, is the thought of 'a polar bear'.

The perception of movements as one's eyes travel over the different parts of a statue is not a percept of the grace of the statue. 'In the one instance one is set to respond to movement and in the other to the statue.' The two attitudes are different yet in both the complete nervous arc is involved. Motor impulses underlie the æsthetic experience just as much as they underlie the kinæsthetic.[2]

Eye-movements then, are of great interest, since the nerve impulses bringing them about, and resulting from them, through the muscle sense organs involved, underlie so much of our mental activity. These nerve impulses resulting in eye-movements may be generated by light falling on the retina from objects, or by sounds.

Head moved instead of eyes:

In some children the head always turns towards the object while the eyes are kept still in their orbits. Sometimes though eye-movements are good in the horizontal, they are poor in the vertical direction. Again fixation may be bad. Any of these abnormalities will lead to but vague impressions at sight though many objects may be seen. Such vague impressions interfere with reading ability, and lead to inaccuracy in transcription and in arithmetic, and kindred subjects. Turning of the head instead of appropriate eye-movements for example, may easily cause the missing of a line in copying from a book or the blackboard.

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[1] H. S. Langfeldt in *Æsthetic Attitude*, 1920.

[2] 'Seeing' colour does not involve muscular contractions and motor response as does seeing form or judging distance.

The physiological basis of colour perception seems still unexplained.

Need to practise looking at distant objects:

In order, both to avoid fatigue of certain neurones, and muscles, and also to practise others, children need to be encouraged to look away frequently to distant objects, e.g. to the spire of a distant church, to an aeroplane or cloud high in the sky, to a bird on a chimney pot. This is especially the case with children living in urban surroundings, where the constant focusing on rapidly moving nearby objects tends to fatigue in certain neurones, while others, concerned with sight of objects at a distance, are too little used. This is one reason among many, for getting classes out to drill in the playground where training of neurones for distant vision can be carried out.

Training eye-movements for near vision:

To train eye-movements for nearer vision, the child must be induced to move his eyes by fixing his gaze on a small bright object fixed to the end of a pointer which is then moved up and down, and from side to side, or in a circle, first slowly and steadily, then more rapidly.

Or a prism, mirror, or torch may be used to reflect light on walls and ceilings in a slightly darkened room and the children's eyes will follow the resultant 'Tinker Bell'. They must be warned that eyes, not heads, are to follow.

By such methods controlled eye-movements may be established during Nursery School years. Movements of both hands and eyes may be controlled through the ear, and at the same time right and left learned, as the child points, or turns his eyes to the right or left, or up or down, as directed.

Co-ordination of fingers and eyes by imitative movements:

About the age of five some imitation of finger movements for a minute or so a day will help towards co-ordination of fingers and eyes, this involving finer movements through the intrinsic muscles of the eye as well as control of the muscles moving the eyeball (see exercises, chap. VI).

Boys are easily incited to practise exercises to improve any defect in eye-movements, when they are told how valuable good eye-movements as opposed to slower head movements will be in cricket!

Wandering eye-movements:

Uncontrollable irregular eye-movements in children above the age of five are an undesirable form of spontaneous movement, which, if not due to fatigue or ill-health, may be due to lack of training in Nursery School years. Such movements, not controlled as to number and direction by any external stimulus, indicate nervousness and faulty functioning of neurones. They illustrate the fact that excessive movement may be indicative of weakness and not of strength. Such spontaneous movements often lead to a child being unjustly stigmatized as careless and inattentive, e.g. if it leads to wrong copying. Blame when the child knows that he was trying, leads to the 'its-no-use-trying' attitude, an unreceptive frame of mind and body, and so to real lack of attention.

Uncontrolled eye-movements may mean the child fails to look properly, and to see exactly where he has put his property away, so later on he fails to call up a distinct image and can't find his things (cp. an adult and her 'lost' spectacles).

Inaccuracy in copying and so forth, should lead to the testing of eye-movements (as well as of eyesight in the more usual sense) and to suitable training, where found necessary, among older children who have failed to profit by that given in Nursery School years (see exercises, chap. VI).

From what has been said (p. 119) such failure may be due to malnutrition or actual illness in the first months of life, or to lack of effective stimuli or to too great stimulation during the formative stages of the first few years.

CHAPTER IV

POSTURES INDICATIVE OF BRAIN STATES

Postures are the results of movements so they may perhaps be thought of as 'frozen movements'. Since they are the outcome of the ratio of action among the neurones, they are important signs of the state of the central nervous system at the moment of observation.

They can be more easily observed, described, drawn or photographed than movement itself. Dr. Francis Warner, in his observations on one hundred thousand children[1] noted the frequent occurrence of the following postures indicative of conditions of the nervous system.

Head balance

In a strong and healthy child the head is held erect, unless something changes its position. Drooping of the head indicates poor functioning among the neurones, often a temporary condition. The head may incline to one side, as often seen in the 'nervous' type of girl.

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[1] Scientific study of the mental and physical conditions of childhood, based upon the examination of one hundred thousand children, in *Cyclopædia of the Diseases of Children*, Keating, Vol. V, 1899.

General balance of the body

When the child is standing quietly, this should be symmetrical, equal on the two sides so that the shoulders are at the same level and the spine balanced straight, the feet should be equally planted on the ground with the knees straight. When the arms are held out in front, symmetry should be maintained in the equal height at which they are placed, with the elbows straight. There should be no slouching or listless attitude.

Irregular balance—with shoulders not held at equal height, back rounded, bent, or twisted over to one side, feet not each planted similarly on the floor, indicates nerve impulses to the muscles of the one side differing from those passing to the muscles of the other, i.e. unequal action in the right and left hemispheres. Hand balance will then also probably show approach to the 'weak' posture in the corresponding hand. (See p. 149.)

Lordosis: When the hands and arms are held forward an alteration in the balance of the spine may appear, with an arching forward in the lower part of the back, while the upper part of the spine between the shoulders is thrown back.

This arching forward of the lumbar spine is due to weakness of action among the spinal muscles, itself due to faulty control by neurones. When a child holds out its hands the centre of gravity of the body is moved forward; in a strong child, with neurones functioning rightly this is not followed by marked change of posture in the spine, but in a weak child with ill trained or poorly functioning neurones, lordosis may follow, often with temporary lateral curvature and unequal balance of the shoulders, while the head and neck are thrown back.[1]

Expression in the face

This is one very obvious type of posture, the result of muscle contractions controlled by nerve impulses. As these proceed from neurones closely associated with those which subserve the higher mental and emotional processes facial expression can often be an accurate index of brain state, past or present.

A healthy normal brain, particularly in children, is indicated by the calm face without wrinkling or puckering in the forehead, symmetrical in its expression and action on the two sides, yet with a bright, lively, changeful expression. This indicates spontaneity (see pp. 115, 118, etc.) and is a hopeful sign of mental aptitude.

When the expression of the face is defective, showing want of changefulness, vacancy, or fixed expression, the brain is either dull or tired, it is lacking in spontaneous activity.

We may describe the visible muscular action seen in a face, and still there may be an expression in it which entirely baffles description. Further, a face may be balanced or moved abnormally by the action of certain muscles, and yet it may carry upon it a good expression. We may describe action in the frontal muscles, the corrugators, the orbicularis oculi, etc., and, over and above this, we have the general expression of the face superadded. Certain terms are useful in describing expression; there may be a fixed expression, want of variation, i.e. one fixed uniform action or balance of muscular tone; or we may have to use more general terms such as 'defective'—'bad'. There may be no expression, i.e. none other than that indicated by form or modelling of features.

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[1] See F. M. Alexander in *The Use of the Self*, on his way to establish the fundamental nervous control of posture.

Expression in the face may be described in three zones:

1. The forehead above the eyes.
2. The eyelids and parts around them.
3. The lower part of the face, cheekbones, nostrils, regions around the mouth.

ZONE I

Frontal Region. The greatest degree of expression is seen in the frontal region, mainly produced by the action of the frontal and corrugator muscles, in the one case we may see the results of the overaction of frontal muscles and in the other of the corrugators, indicating useless activity in the neuronic pattern controlling those muscles.

Frontal Muscles overacting. There is a pair of muscles in the forehead, placed vertically under the skin and attached at the eyebrows; by their action they raise the eyebrows, and produce horizontal creases in the forehead, which may be shallow or deep; in other cases the action is fine, producing minute creases. If this frequently occurs, it is a bad sign in children and is most common in those of unoccupied mind and untrained mental action.

This muscular overaction does not necessarily erase expression. It is often a sign of spontaneous action in the neurones controlling the muscles and may be seen in children from earliest infancy; the condition may be temporary, and, having lasted a sufficient number of years to produce permanent creases in the forehead, it may pass away. It may appear as part of a spreading area of action in the face, e.g. in stammering. Activity in these muscles is often less when the child is at work or being talked to, than when let out to play; the mental attitude of quiet attention is that under which the frontal area is most quiet. This sign is far more frequent in boys than in girls.

Corrugation. Knitting the eyebrows, drawing the eyebrows together. There is a pair of muscles in the forehead, placed horizontally between the eyebrows which draws them together, thus producing vertical puckerings on the forehead above the nose, or only a fine wrinkling of the skin, which contributes to a dull appearance of the forehead.

Corrugation (knitting eyebrows), may coexist with overaction of the frontal muscles (frowning), producing a puzzled expression, or, if deep, a 'scowl', as in ill-temper.

This sign (corrugation) seems more closely associated than any other single sign with some forms of mental stress and may be seen in children suffering from the effects of fright, illusions, etc., it may form part of a fixed immobile expression. It indicates a useless overflow of nerve energy accompanying some mental act.

ZONE 2

Eyelids and Parts Surrounding. Orbicularis oculi and 'fullness' under the eyes:

In the second zone the expression largely depends on the nerve impulses which are being received by the orbicularis oculi. This is a thin muscle which encircles the eyelids, and being attached to the skin gives tone to the lower lid, so that its convexity is seen. In a strong and well-toned face the lower lid appears clean-cut and well moulded, the rotundity of the eyeball and convexity of the lower lid are shown in sharp definition of outline, due to good tone in this muscle. In smiling and laughter this muscle causes puckering of the lower lid. When this muscle is relaxed and toneless, the skin of the under lid bulges forward and is baggy, causing fullness under the eyes. This condition is removed temporarily on making the child smile or laugh. It is indicative of fatigue, exhaustion, low brain power, malnutrition, or other bad condition of the neurones; it frequently accompanies recurring headaches.

ZONE 3

Lower part of face. In the third and lowest zone the mouth may be habitually slightly open giving a dull vacant look. This usually indicates the mouth breather probably suffering from adenoids. In this zone there may be grinning or over-smiling about the angles of the mouth, temporarily widening the opening, the lines on the face may be slight or deep. Over-smiling or grinning is usually symmetrical but may be unequal on the two sides of the face.

With low class brain conditions it is sometimes seen as almost the only facial movement, occurring upon any stimulus as a uniform movement, almost as frequent as overaction of the frontal muscles.

If habitual, grinning and in particular the finer forms of over-smiling often leave permanent naso-labial creases, marked upon the skin, these may remain after the habit has been lost. If the skin be thin, a duplicate or triplicate naso-labial crease may be formed; this is more common in neurotic than in imbecile subjects.

Persistent depression of the angles of the mouth often indicates some present pain in the body.

Hand balance

The hand is second only to the face in importance as an index of neuronic action, and therefore of brain state.

Method in Observing Hand Balance. In observing it as such an index, the hand should be held out at arm's-length and free in front of the body, simply balanced as nerve impulses from the brain control the muscles. If the hand is holding something, such as a pen, that is largely a reflex act controlled by nerve impulses due to external stimuli from the pen, the fingers are not then controlled by impulses due only to the brain condition of the moment. For the hand posture to act as index of the brain condition, that state, and not a pen, must govern the posture. The hand is free when hanging over the arm of a chair, less free when resting on the table.

For detailed observation of hand posture the child should be standing, and should be told: 'Put out your hands in front with the palms downwards, and spread the fingers,' or the observer (seated, so that her own arms when outstretched are level with those of the child) may say: 'Watch,' putting out her own arms in the desired position. After dropping her arms the observer can then say to the child: 'Do as I did.' If it is desired, as here, simply to observe the posture of the child's arms and hands, the observer's holding of the posture must be quite momentary that imitation may be avoided. The fingers should be slightly spread, for, if they touch one another, they give mutual support and, twitches which might occur when the fingers are separated, will be prevented. (See p. 151.)

The straight hand. Normal balance

When the hands are thus held out to command, the normal balance should be with both arms horizontal, on a level with the shoulders, the hands turned palm downwards, the width of the chest apart, the elbows being quite straight. The arm, the hand and its parts should be all balanced in the same plane, the palm of the hand spread flat not contracted laterally as in the 'Feeble' hand (Fig. 8, p. 149), the fingers and thumb straight with the palm, the fingers steady when separated. (See Fig. 1 below.)

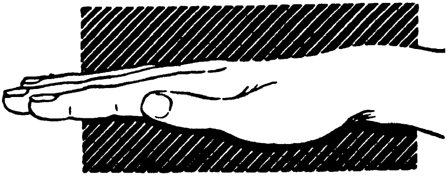


FIG. 1. THE STRAIGHT HAND

This is the normal posture indicating a robust well-balanced central nervous system.

As the maintenance of the posture depends upon the uniform action of a continuous stream of impulses from certain neurones to the muscles, half a minute is the longest period during which the hands should be held out in this fixed position for observation.

A slight deviation from such a level and exactly balanced position is not to be considered necessarily as a sign of a departure from health. In a strong healthy child of say five years old and upwards, the hands will be held out fairly straight from the shoulder but the arms may not be held quite at the same level, the innervation of the left is often a little weaker and it is held a little lower than the right.

A group of children, say ten years of age, may include 5—10 per cent who vary more markedly from the perfect balance and typical posture. Certain deviations at once suggest that the child concerned is nervous, excitable, or exhausted.

Dr. Warner found difficulty at first in describing the postures seen in precise language. While visiting Florence he noticed that the posture of the hands of the Venus de Médici was exactly similar to the posture he had so often seen in nervous children. Later at the British Museum he saw the Venus side by side with the Diana (Figs. 4 and 3, facing p. 146), feminine coyness and nervousness side by side with the expression of energy and strength, and contrasting the hand postures he saw that they were in direct antithesis. Looking at the marble hands it became much easier to describe the postures in precise language.

The nervous hand

In the hands of the nervous woman the wrist is slightly flexed or dropped, the knuckles are moderately extended back beyond the straight line, the finger joints being slightly bent. The thumb is extended backwards, and somewhat drawn away from the fingers. The palm is slightly contracted laterally so looks narrow, arched on the upper and hollow on the under surface.

This posture Dr. Warner called the 'Nervous Hand'.

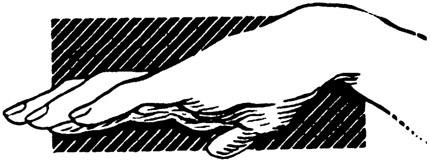


FIG. 2. NERVOUS HAND

It indicates some degree of weakness together with some over-action or excitability of certain brain neurones but is not usually accompanied by mental dullness. It is the posture commonly seen in weak excitable nervous children, such as are hot-tempered but affectionate, often they are tooth grinders and very liable to recurrent headaches. Sometimes they have capricious or voracious appetites, or disturbances of digestion and vague debility without disease. The posture is common in children with slight chorea.

Such a nervous hand posture may be seen represented by modern artists and in antique bronzes and drawings on vases, or in sculpture.

The energetic hand

In the Diana (Fig. 3 from the British Museum), we see the figure of a strong, energetic woman. Our common experience tells us that it is such. Her right hand is lifted, and is engaged in holding a spear or dart, which she is about to hurl; this hand is, therefore, not available as a sign indicating the mental condition. The left hand, however, hangs down, and is free or unoccupied, and by its posture affords us evidence of the active or mentally energetic condition of the brain. The balance of the parts of the body indicates to us the balance of the action, among the neurones, the left hand illustrates the posture termed 'the energetic hand', (Figs. 3 and 5).

The wrist is extended backwards, the fingers and thumb are flexed.

If we compare this energetic hand with the hand in the nervous posture, we see the former to be the direct antithesis of the latter. In the weak woman the hand is flexed at the wrist, the fingers and thumb bent back at the knuckles; in the strong woman the wrist is extended backwards, and the digits are flexed. This is an example of one posture being the antithesis or direct opposite of the other; Charles Darwin made much use of the principle of antithesis in his work on Expression.

The straight extended hand has been described as the normal type, and two postures as deviations therefrom; one, the energetic hand, a perfectly normal and

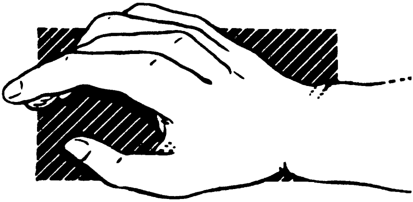
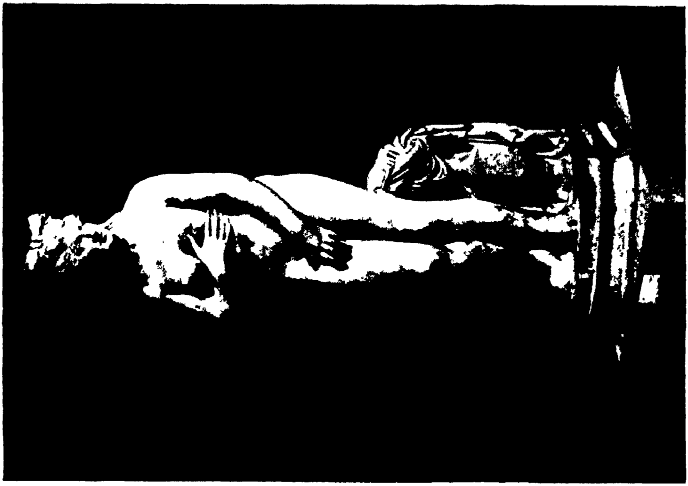


FIG. 5. ENERGETIC HAND



healthful condition, the other the nervous hand, which indicates weakness and excitability. An example of the energetic hand in real life may often be seen in the attitude of little children, say between three and four years old; when called and shown something they like; they run with arms stretched out and hands in the energetic posture, wrist extended, the fingers slightly flexed.

Straight hand with thumb drooped

One of the first departures from the signs of perfect strength is the posture to be described under the name of the 'straight hand with the thumb drooped'. This may commonly be observed in conditions of health, when fatigue or slight weakness occurs. It is similar to the straight hand, but the thumb, with its metacarpal bone, falls slightly, thus approximating the latter towards the palm. Dr. Warner tells how he was once able to point out this sign to the headmaster of a large school. 'I had looked over the lower classes of the school without noticing any unusual signs among the boys. When, however, we came to the first class, and these boys held out their hands, I observed that every boy, with two exceptions, held the hands straight,

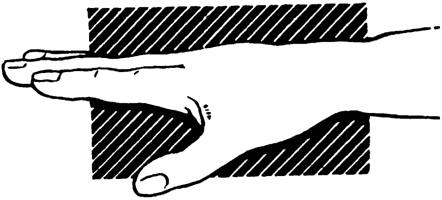


FIG. 6. STRAIGHT HAND WITH THUMB DROOPED

with the thumbs drooped. This class had recently been engaged in their annual examinations.'[1]

It may be observed that early in the morning the hand is held quite straight while in the latter part of the day the thumb tends to droop. In such cases, food, and a little rest, will usually restore the normal posture, and this, the first sign of fatigue, will pass away. This posture is, in fact, the first stage towards the feeble hand, still to be described.

Natural position of hand in rest

Figure 7 shows the natural position of the free hand when at rest, as it may be seen hanging over the side of a chair, or lying in the lap. The hand in rest is a natural position, with slight flexion of the wrist and fingers, and slight arching of the metacarpus or palm of the hand; it is also common in slight fatigue without exhaustion, and may be seen in healthy sleep, when no energizing nerve-impulses are passing from the brain to the muscles.

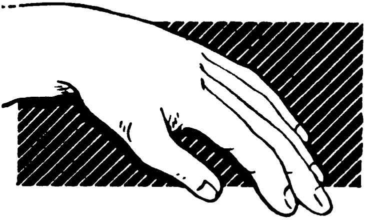


FIG. 7. HAND IN REST

Feeble hand

The 'feeble hand', showing weak hand balance, is an exaggerated form of the 'hand in rest'. The degree of flexion of all parts is greater, the hand when held out is slightly drooped or flexed at the wrist, the palm slightly contracted or arched laterally, and the fingers slightly bent. The type varies; with less degrees of weakness the hand is as in the normal with the thumb drooped only; in exhaustion or great feebleness the palm is more contracted or adducted and the degree of flexion is greater.

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[1] Dr. F. Warner in The *Study of Children*, p. 83.

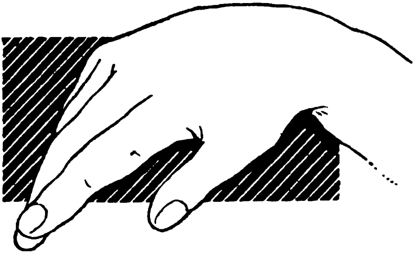
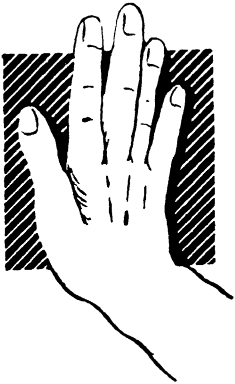


FIG. 8. FEEBLE HAND

All these signs indicate less action in the muscles and less force produced in the neurones controlling them. If, in the case of a slightly feeble hand posture the child looks at the observer's straight balanced hand and imitates it, the action in his brain is controlled to be more like that in the observer's. The necessary impulses pass from the neurones to the muscles and the hand straightens up. Weak hand balance is seen in the listless, careless, or tired, and is often more marked on the left side. The child will also often keep the left hand at a lower level than the right.

Hand in fright

Two typical postures of the hand still remain to be described. The 'hand in fright' (Fig. 9) is a posture no often seen; it is a modification of the energetic hand the wrist and fingers being all extended. It is wel represented in the statue of Cain (Fig. 10) and ir several members of the Niobe Group at Florence.



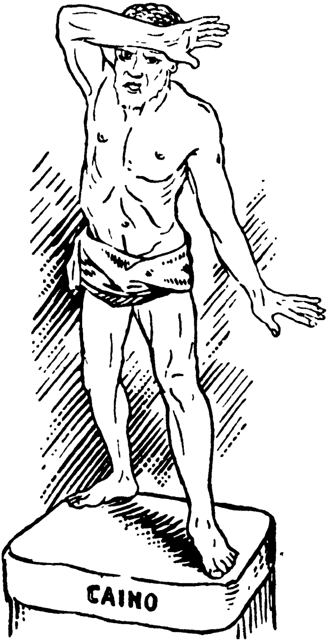


FIG. 9. HAND IN FRIGHT FIG. 10

Convulsive hand

When a child is convulsed by epilepsy or brain disease, we usually see the hand clenched as a closed fist. The thumb is strongly flexed on the palm of the hand. while the fingers are closed over it, thus forming a closed fist, while the palm is arched or contracted by bringing its sides together. (Fig. 11)

This position is never normal, but in a few cases may occur as a simple matter of habit. The convulsive hand may be seen in a child in passion, and it sometimes occurs during a strong effort of self-control. It is often seen in people when about to have a tooth drawn.

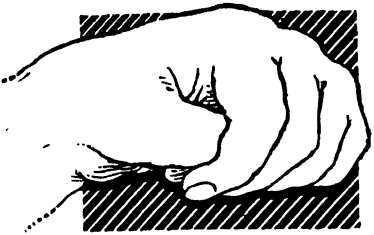


FIG. 11. CONVULSIVE HAND

The eight types of hand postures will help in description but various deviations from these types will often occur.

Finger twitches

When the hands are held out for inspection with fingers spread there may be twitching movements in the fingers. These may be up and down (flexion and extension) or lateral. Twitches often accompany nervous hand posture in weak conditions.

With the 5--10 per cent of children who may fail to present the normal 'straight' hand (p. 143), various remedial measures may be tried. Detailed observation of such children's hand postures, repeated week by week, will show how far such measures are improving the faulty functioning of their neurones.

Only a few suggestions are given in this book probably many physical and educational condition need improvement for any child persistently presenting either the nervous or the weak type of hand balance.

CHAPTER V

SPECIMEN REPORTS

This chapter contains at once the summary of, and the reason for, the writing of this book.

Until students have repeatedly tried to describe children *in writing* in the way suggested in the following 'Reports', they can have no idea of the difficulty, the fascination, and the worth whileness of such written statements. They will inevitably be surprised to find how often they have failed to describe observed movements and postures, but have instead slipped into vague generalities. It will need written observations of many children before such a statement as 'Spontaneous movements are too frequent for her age' (see p. 166), can safely be made about a child.

Schedule for report on the postures and movements of a school child, considered as signs of the good or bad functioning of the child's neurones

Name.

Age last birthday. Average age in class.

SKELETON SCHEDULE

GENERAL BALANCE OF BODY (see chap. IV).

1. Of feet and legs.
2. Of shoulders.
3. Of Head.

FACIAL EXPRESSION (see chap. IV).

1. Frontal Muscles.
2. Corrugators.
3. Orbicularis Oculi.
4. Mouth.
5. General.

HAND BALANCE (for types see chap. IV).

MOVEMENTS (see chap. III).

A. SPONTANEOUS.

1. Normal.
2. Too few.
3. Too many, give parts specially motile.
4. Twitching.
5. Uniformly repeated.

B. RESPONSE MOVEMENTS.

1. Normal.
2. Too quick.
3. Too slow.
4. Pause long.
5. Pause absent.

C. SPREADING AREA.

Conditions most frequently causing (e.g. fatigue, hunger, poor ventilation, too strong stimulation, etc.).
Type of stimulus causing.
Parts most frequently involved, usual starting point if any, sequence of movement.

SPECIMEN REPORTS

Eye-Movements.

- Fixation.
- Vertical.
- Horizontal.

General Nutrition.

- Weight. Normal—Above or below normal.
- Signs of fatigue.
- Are they permanent? What produces?
- If disappear, what helps this?

School Report.

- Conclusions, and suggestion as to training.

A normal child

(Adapted from Dr. Warner's *Study of Children*)

(See fuller description of a healthy child on page 162)

John Smith.

Age last birthday—9 years. Average age in Class: 9 years, 6 mths.

GENERAL BALANCE OF BODY.

Stands well, feet apart, legs straight, knees not bent.

Shoulders level.

Head forward and well up but chin not tilted.

FACIAL EXPRESSION.

No horizontal lines in forehead.

One very slight line due to corrugator action between eyebrows.

Good tone about eyelids; no bagginess of under lids.

Lips just parted in straight lines.

Expression bright and changeful. Intelligent looking face.

HAND BALANCE.

Straight on level with shoulders.

MOVEMENTS.

Spontaneous.	Normal. Fingers steady when hands held out.
Response.	Normal. Active and accurate. Sight and hearing—good.
Spreading Area.	Normally nil, some shuffling of feet, towards end of morning in school.

EYE-MOVEMENTS.

Fixes eyes well.

They follow a moving object accurately, both horizontally and vertically.

GENERAL NUTRITION.

Healthy and well nourished. Weight 60 lb. Good colour in face and lips.

SCHOOL REPORT.

A good child; is bright and intelligent. Recites well, quick at arithmetic, is rather high in school for age. Attendance regular.

CONCLUSIONS AND SUGGESTIONS.

A healthy, well-made boy; he seems well trained in action of body and in mental power. He is likely to profit by higher education when old enough.

DATE.

'Nervous' children

There is a class of children, commonly met with in every school, termed 'nervous children'; e.g. such as are apt to complain of headaches, are difficult to get off to sleep, bad sleepers, talking at night and grinding their teeth, while in the morning they are tired and not ready for breakfast. They are often bright enough mentally, affectionate, and too emotional. There are children who are delicate without having any disease; who are never laid up with any definite illness, but they are not strong, cannot walk far without getting tired; some days they are too tired to do anything and must rest; capricious in appetite, yet sometimes ravenous, but losing weight. A typical nervous child is generally well made in body, with a good head and well-cut features, a fine skin and light complexion; she or he may be tall and rather thin, with subnormal body weight. In the movements and postures we see indications of weakness and over-spontaneity.

The general balance of the body, as the child stands, is usually asymmetrical, with the head slightly drooped and inclined to one side; while the spine is perhaps bent a little to one side, with unequal shoulders, and the feet unequally planted. The eyes wander much, in place of being directed to objects and fully controlled through sight and a spoken word. In the face, expression may be somewhat diminished, with fullness under the eyes indicating fatigue. When the hands are held out in front, asymmetry in balance of the arms is frequent, the left hand usually being held lower, while the 'nervous hand-posture' is marked more on the left than on the right (see fig. 2, p. 145). As the hands are held out, the shoulders and upper part of the spine move backwards with an increased curve of the forward bend in the loins (lordosis), as a compensation in balance owing to weakness in control of the back muscles.

The fingers probably show twitching movements, if they are held separate from one another, so as to be free to move.

These signs show weakness, with over-mobility; and, if the condition is accompanied by a body weight falling month by month or week by week, the child may, if overworked or if placed under mental stress by circumstances, or if frightened, pass on to the state called chorea. In mental habit such children are usually quick in learning, talkative, playful, and often laughing; in social life, they are gregarious, seeking one another's company, and, as they are usually imitative, may prove a source of mental excitement to one another. On looking further at such a child, you will probably find that the face is the best nourished part of the body, the limbs being thin; the teeth are very likely flattened at their tips from the constant habit of tooth-grinding. Appetite is very variable; these nervous children are very difficult to feed; at times appetite fails much, and again at another time they are voracious though they may still lose in weight.

If such loss continues, or there is increasing faulty posture, lax muscles, drooping sagging stance with loss of energy, control and concentration, often exhibited in restless and emotional outbursts, only a doctor can diagnose and deal with the cause.

For example such cause might be psychological, or due to suprarenal deficiency, to intestinal trouble, to a pre-rheumatic condition, etc.

A nervous child

Adapted from Dr. Warner's *Study of Children*

(See also fuller description of a nervous child, p. 165.)

Sarah Jones.

Age last birthday—12 years. Average age in class—13 years.

GENERAL BALANCE OF BODY.

Feet unequally planted.
Left shoulder lower than right.
Head slightly drooped and inclined to left.

FACIAL EXPRESSION.

Some corrugation.

Fullness under eyes; this disappears momentarily in smiling.

Lips rather tightly closed.

Expression a little dull and wanting in changefulness.

HAND BALANCE.

Left balances lower than right, each is in the nervous posture, especially marked in left. Separate fingers twitch.

When hands are held out, the shoulders fall backward and the spine is bent forward at the loins (lordosis).

MOVEMENTS.

Spontaneous.

Fidgets while standing, fingers play with frock, foot taps. Head tilted back.

Response.

Imitation of finger movements, sometimes inaccurate and too quick, pause too short.

Spreading Area.

Extra movements with things on desk when settling down to work. (Often lead to hurling things off it!)

EYE-MOVEMENTS.

Eyes wander, but fix on and follow object if told to.

NUTRITION.

Rather thin and pale. Weight 75 lb.

SCHOOL REPORT.

Quick at lessons, recites well. Talkative in school, playful and often laughing. Is fond of the society of other children like herself.

CONCLUSIONS AND SUGGESTIONS.

This may be said to be a nervous child; well made in bodily development, but rather under weight for her height; though quick and bright mentally, she shows so many abnormal movements and postures, that, unless she is brought under better control, she is likely to become an hysterical girl after leaving school at fourteen years. She needs careful training and physical exercises to remove each fault in detail.

A strong, but dull and backward boy

(Adapted from Dr. Warner's *Study of Children*)

Edward Baker.

Age last birthday—11 years. Average age in class—8½ years.

GENERAL BALANCE OF BODY.

Slouches, no exact symmetry of balance.
Feet turned in.
Shoulders hunched.
Head pokes forward.

FACIAL EXPRESSION.

Fine horizontal lines in forehead.
Good tone in orbicularis oculi.
Mouth slightly open in repose.
Bright expression, but not very intelligent looking.

HAND BALANCE.

Left held lower than right; balance in feeble posture.

MOVEMENTS.

Spontaneous. Too few. Dawdles out into playground after school, or at 'break'.

Response. In imitation of finger movements rather slow and uncertain. Pause too long.

Spreading Area. Tongue protruded when writing.

EYE-MOVEMENTS.

Can fix eyes well; looks about by moving head, not eyes.

NUTRITION.

Good colour in face and lips. Robust. A strong boy. Weight 76 lb.

SCHOOL REPORT.

Does work in school but is slow and inaccurate, and could not pass examination. Dull, but not defective.

CONCLUSIONS AND SUGGESTIONS.

Appears capable of work. Needs drill to quicken him and improve gait. A few minutes employed daily in class-exercises in imitation of movements and eye-movements would improve his brain-power. Possibly would do better with boys more of his own age.

A healthy normal child

(Adapted from Dr. F. Warner's *The Nervous System of the Child*)

Extended description including Characteristics of Brain Action. (See Chapter II).

A child well developed in body and brain. Much spontaneity, but it is under control.

Willie Smith.

Age last birthday—8 years. Average age in class— 8½ years.

A NORMAL CHILD

General Balance of Body.

Stands well. Legs straight.
Feet well separated.
Shoulders level.
Head forward and up but chin not tilted.

Facial Expression.

Forehead unlined.
Good tone in face about eyes; increased when he smiles.
Lips straight, lightly closed.
Lively, looks pleased and interested.

Hand Balance.

Hands held out straight. After hands have been kept out half a minute the head droops to the right, but is quickly erect again when hands are put down. Imitation of finger movements fairly accurate.

Movements.

Spontaneous.	Normal.
Response.	Slightly too rapid, and pause short.
Spreading Area.	No habitually repeated over-action. When a little fatigued, his head droops.

Eye-Movements.

Turn well to fix on teacher's hand when imitating movements.

Characteristics of Brain Action.

Spontaneity.

Up to average for age; good tone of face, and is always ready for action or to make some reply.

IMPRESSIONABILITY.

Present in a degree indicating that he will probably develop good capacity for control through his senses and for co-ordination, e.g. quick to notice all that happens in class, saw that a new p.c. had been added to a board, was first in class to hear the cuckoo!

INHIBITION.

Is generally quiet during class, and attentive; after work is fresh and full of play and talk.

CONTROL THROUGH SENSES.

Action fairly accurate as controlled by sight of what he looks at.

CO-ORDINATION.

Imitates manual exercise, with fair accuracy as to the fingers moving; not quite correct in time of action.

MUSCULAR SENSE.

Can distinguish the weight of seeds; also makes measurement at sight fairly well; counts objects accurately.

COMPOUND CEREBRATION.

Not very successful, except under guidance (e.g. in acts of comparison).

RETENTIVENESS.

He evidently remembers some of the points he has been taught. His thoughts do not yet follow in as good order as his movements.

RESPONSE.

When he answers a question, his reply is prompt, whether correct or not; there is very little pause for thinking. His replies come out like reflex actions rather than as resulting from a train of thought which occupies some interval. Stimuli from question co-ordinate patterns, but pause too short to allow of much compound cerebration.

PHYSICAL HEALTH AND NUTRITION.

Healthy and well. Weight 55 lb., average.

SCHOOL REPORT.

A very bright but mischievous boy, is liked by his schoolmates. Fairly attentive and interested in his lessons; reads well, and answers very promptly.

OBSERVER'S REPORT ON CHILD.

A well-made healthy child, with good brain activity. The healthy spontaneity of childhood is well marked; this is easily controlled through eyes or ears, and resumed in a healthy manner when control is removed. There was no excess of extra movement accompanying his action but as fatigue commenced from the strain of holding out his hands his head began to droop.

A child of nervous type

(Adapted from Dr. F. Warner's *The Nervous System of the Child*)

Mary Brown.

Age last birthday—14 years. Average age in class—13½ years.

GENERAL BALANCE OF BODY.

Does not stand straight or keep quite still.
Feet unequally planted.
Shoulders not at same level.

FACIAL EXPRESSION.

Some corrugation and horizontal lines in forehead. Want of good tone about the lower eyelids, but this disappears when interested, and in smiling. A spreading smile often seen, and sometimes twitching of the mouth.

HAND BALANCE.

Hands held out promptly in response, the left a little lower than the right, while neither is on a level with shoulder. Each balances in the 'nervous posture', especially the left; this becomes more marked if the effort is maintained. There is some bending of the lower part of the spine, while the shoulders are thrown back.

MOVEMENTS.

Spontaneous.

Fidgets while standing, feet shuffle, fingers twitch. Head often turned about, the eyes wander, she smiles frequently. Spontaneous movements are too frequent for her age.

Response.

Prompt, action is quick and well imitated from others, but is often accompanied by some extra movements besides those under control. Generally no pause.

Spreading Area.

Extra movements with the pen seen before writing, while at times the fingers twitch on the pen. The head often tilts upwards while thinking; or is held on one side when speaking, or when the hands are held out. She tends to laughter and talkativeness.

Eye-Movements.

Can fix eyes well, but they often wander when not directed.

Directed eye-movements good, both vertically and horizontally.

Characteristics of Brain Action.

Spontaneity. See Spontaneous Movements above. She is active and imaginative in play and in dramatic work.

Impressionability.

Quick to receive all impressions, looks at everyone who speaks in the class; is not always completely under control.

Inhibition.

While prompt to stand when directed, fidgets with dress or hair; she is never quite still.

Control Through Senses.

Good capacity, but sometimes listens and looks about instead of seeing the blackboard or map demonstration. At times starts and fidgets when spoken to.

Co-ordination.

Imitates finger movements well, but is not quite accurate. Such action is often accompanied by some extra movements. Speaks well; good at games.

Muscle Sense.

Appreciates and compares weights in the hands well; knows coins by feeling them. Estimates dimensions better by feeling with the hands than at sight.

COMPOUND CEREBRATION.

Physical exercises well performed; can lead the class without being guided. Proceeds systematically to examine and describe a plant as previously taught. Generally repeats a lesson correctly and not parrot wise.

RETENTIVENESS.

Memory really good; but forgets where to find things from not looking to see when putting them away; can retain facts learnt, but does not always use them aright.

SPREADING AREA.

See under Movements. Sometimes there is confusion in replies; facts of history are remembered but given in the wrong places.

RESPONSE.

Often answers without a pause for thinking.

PHYSICAL HEALTH AND NUTRITION.

Not pale, but a little thin for her stature; weight 98 lb. Average weight for age is 100.32 lb., but the child is a little above the average height; further, she has probably not yet completed her growth which last year increased by 1.75 inches as against an average of 1.57 for her age, while weight increased only 8 lb. as compared with the average 9.14 lb.

SCHOOL REPORT.

In disposition affectionate, sometimes loses self-control, becoming emotional and passionate.

OBSERVER'S REPORT ON THE CHILD.

This girl is well developed in head and features, as well as in bodily growth. There is a little asymmetry in nerve-muscular action; some tendency to spreading activity in the brain, both for movement and thoughts, and, as this is not always under control, we see what are commonly called some signs of the nervous type.

Mental capacity, as is usual with these children, is quick and the memory retentive, but expression is not always exact.

She is a little pale and under weight; general health culture together with continued training are needed. Her condition is hopeful, but she might easily be spoilt, becoming anæmic and dyspeptic if health is not cared for, or neurotic and excitable and hysterical if not properly controlled during the next two or three years; while under bad hygienic conditions some permanent ill-health is likely to arise.

CHAPTER VI

EXERCISES

Using the imitation of finger movements to increase the controllability of the neurones of the brain,

A. by visual stimuli B. by stimuli received from contracting muscles (sense of muscle tension)

Facts on which the Exercises are based

Movements involved in 'skills' (e.g. wood-carving, writing, reading, handwork, etc.) are controlled by the coaction of innumerable neurones.

Before these neurones can coact efficiently and enable their owner to carry out the desirable or useful movements involved in 'skills' the following conditions must be fulfilled:

1. Neurones must have had time to mature and must be 'good' in themselves. (Depends on heredity.)

2. Neurones must be well nourished. (Depends on right food, well digested, good circulation, fresh air, sunlight.)

3. The particular neurones controlling the required pattern of movement must be suitably co-stimulated through eyes or ears or muscles, at the moment when

the particular movement is wanted. Repetition of such stimulation producing 'practised' response will be needed.

4. The neurones should have been previously rendered apt to respond accurately to stimuli of the class which normally sets off the required train of movements, e.g. such a 'class' of stimuli are (1) changes in light conditions, as caused by the sight of objects, (2) changes in sound conditions.

1 and 2 depend on the child's parents and as a rule the teacher considers and carefully provides for 3. For example take the process of acquiring the necessary Neuronic Pattern for Movements in writing at 7-8 years of age. Gradations of light from copy, page and pen, changes in tension in muscles of forearm are the chief sources of the stimuli. These stimuli pass via nerves from eye and muscle to certain neurones in brain and spinal cord and cause them in turn to pass on stimuli to other neurones and so on. Finally a pattern of neurones is stimulated which causes some muscles to relax while others contract and so the movements for producing certain letters are made.

Teachers provide 'clear copies', a certain position of desk, eye, and hand with regard to the light and also definite positions of wrist and fingers on desk and pen in order to ensure the best stimulation of the right neurones at the right moment.

But 4 is neglected.

Object of such exercises

The exercises outlined in this chapter are designed to provide in part for this neglected matter—*the generalized* *preparation of certain neurones for control by external stimulation.* They are not intended to produce any particular skill any more than do Swedish drill or dancing -- which train the neurones controlling the larger parts of the body—produce particular skills such as are needed in swimming or in golf. But they do prepare neurones to coact so that responses are more accurate to those stimuli through eye and muscle which bring about skill in reading, writing, etc. A physiological basis for connected thinking is prepared by such imitation, though actual thought processes should not be stimulated at the moment.

Method of giving the exercises

The method is to train the child's brain for five to ten minutes daily by the imitation of *finger* movements, partly A. imitated at sight, partly B. imitated by feel. (Transfer movements.)

A. Visual imitation

The child stands, and is asked to do what he sees the teacher do.

The teacher, who is seated, stretches out his right hand, in front, level with the shoulder, hand palm down, each finger straight, thumb not drooped, i.e. a straight balanced hand (chap. IV, p. 143). He separates his fingers and proceeds to flex different digits in turn, sometimes one at a time, sometimes two, sometimes three together, sometimes returning one digit to the original straight position before he flexes the next, sometimes not. Or, he may move the digits laterally.

Flexion at knuckles, at palm, at wrist are further varieties. Fewer groups of neurones are involved, i.e. there is less brain work, when fingers are moved singly than when two or three move at a time.

Lateral movements involve more brain work then flexions.

At frequent intervals the hand will be dropped to rest at the side, always a fresh series of exercises will be started from a straight balanced hand. Left hand and right hand may be imitated in turn. The pupil exactly imitates the posture and movements of the teacher's hand as the latter produces each movement.

The teacher sits, for if he stands, his outstretched arm and hand will be above the child's shoulder level and he will tend to slope his arms up towards the teacher's. This uses up energy needlessly.

Some children will be seen to waste energy and to show lack of control by visual stimuli, for they will shoot out their arms rapidly and with far more force than the teacher has exhibited.

Naming thumb, A; index finger, B; middle finger, C; ring finger, D; little finger, E; a series of exercises might be as follows:

The joint bent in first exercise being here at junction of fingers and palm of *right* hand of child. Teacher will have *left* hand extended and make the following movements separately, slowly, one after another, at equal intervals of time, so that the child can see them individually and reproduce each movement, bending or moving each finger to the same degree as the teacher's. After each movement the hand will be returned to the straight balanced position. This is indicated in 'Exercises' below by the following abbreviation—*N.B.* (; =straighten).

EXERCISES

EXERCISE I. Bend thumb A; A and B; A; B; and C; B; C; D; E; Drop hand. Raise both arms above head and drop to side.

EXERCISE II. Teacher extends right hand in straight balanced position. Child left.
Bend A, B, D, C, E, together; A, E; E only; Drop hand. Rest. Raise left to straight balance.

EXERCISE III. B moved from side to side without bending it up or down; C bent at knuckle; Drop hand. Rest.

EXERCISE IV. A; B moved from side to side; C bend and straighten; E moved from side to side.

These exercises can be varied to any extent and it's a good plan at the end of the 5 to 8 minutes given to them per day to let the child give some to the teacher.

Need for accuracy in imitation of time and quantity of movement:

The exercises will only be of value in training neurones for accurate response to visual stimuli, if there is real imitation in the time and quantity of movement as well as of the actual finger moved. Also the teacher must guard against using a routine order of the exercises which may allow of the children doing them partly from memory. Any such thought process should be discouraged as likely to lead to 'spreading area of action' among the neurones, and so to dissipation of energy. There may be failure to produce a well-defined pattern among the neurones, a state which is the physical basis of mental confusion. The movements must be slow and careful so that they can be distinctly seen by the child.

Control of Neurones so established resembles the control needed for 'concentration':

The kind of control of neurones which is obtained in such accurate imitation is that which is wanted when 'concentration' in mental processes is desired, and, as the neurones involved are also those linked with both fingers and eyes, through which evolution of the higher brain has been brought about, these exercises may be expected to prepare the child's brain for such mental concentration.

Need to avoid unnecessary speech during exercises:

If mistakes occur, say in the time of any movement, the teacher should not talk about the time, saying 'You moved that finger too quickly' (or 'too slowly'). But he should (by imitation) have the hand dropped to rest. Then start again from the position of straight balance this time greatly exaggerating the slowness or rapidity of his own fingers. If there is talking the child tends to look at the teacher's face rather than at the fingers and to attend to the auditory rather than to the visual stimuli which are reaching him.

B. Imitation by 'feel' (transfer movements)

These make use of the fact that stimuli reach the neurones from those muscles which are producing finger movements.

The child stands up with both hands extended in front in position of straight balance (p. 143).

His eyes are bandaged, and he is told: 'Do with your right hand what you feel me do with your left.' The teacher then flexes and (or) moves laterally the digits of the child's left hand and the child imitates by 'feel' (i.e. by means of stimuli passing to the brain from the muscle sense organs themselves) with his right hand fingers, reproducing each movement one at a time.

Needless to say all fatigue must be avoided.

In both types of exercises (A and B) too great accuracy cannot be expected at first. Children of seven or under will probably not attain perfect accuacy and will also show a good deal of extra movement. Continued inaccuracy in older children may have different causes (see 1 and 2, page 170 in this chapter), often in the case of visual imitation, inaccuracy is due to untrained eye-movements, which may need extra training first or simultaneously.

Some reasons for using these exercises involving this particular type of imitation:

(a) 'Co-ordination of eyes and fingers' is recognized as necessary for many human 'Skills'. 'Co-ordination' means that after co-stimulation certain neurones coact.

(b) Co-ordination for one skill is often no help towards co-ordination for another—even the reverse—i.e. nerve cells which have acquired the habit of co-action in the one pattern are not thereby necessarily made able to enter more easily into some other pattern.

(c) Stimulation (via eyes, ears, muscles) assists the nutrition and development of neurones and increases their readiness to coact in patterns.

These exercises seem to satisfy all three conditions without the disability (due to 'habit') implicit in (b).

Some of the important neurones connected with the eyes and finger moving muscles are gently co-stimulated and caused to coact. Yet the patterns thus formed are not stereotyped by exact repetition for no 'memory' work is allowed, the patterns are at once dissolved, having rendered the cells concerned more apt to respond to future stimulation when they shall have become sufficiently mature for the child to acquire such actual skills as writing, piano playing, etc.

Belief in the value of such exercises for eyes and fingers is further based on the fact that the small parts of the body display great spontaneity of movement in the young of Man, a spontaneity which is absent in other creatures,[1] is much less in the mentally dull and usually completely absent, in the worst cases of mental defect. Much of the playfulness of lambs, kittens and puppies is a display of spontaneity in their larger parts similar to that seen in children just released from school.

Recall again the slow unceasing movements in a well-nourished baby's finger. Lift the lids of the sleeping infant and you will often find the eyeballs moving. These movements mean that frequent, gentle (intrinsic) stimuli are passing back from the muscles controlling those fingers and eyes to certain neurones (see chap. I, pp. 38, 60, etc.).

Work with lower animals has shown that cells which have been recently gently stimulated are especially ready to respond to an external stimulus (such as light changes reaching the retina) and to coact producing co-ordinated movements. Probably then because of the spontaneous movements, the neurones connected with fingers and eyes have very easily responded to control by such external stimuli, and the suggested exercises are therefore following lines along which evolution has already gone far.

---

[1] Perhaps the slow movement of the tip of a cat's tail is an instance of such spontaneity of a 'small part'!

Further these same brain cells—together with those controlling movements concerned in speech—have more to do with the development of mental powers than any other parts of the brain. Any exercises which increase efficiency of such neurones for response to stimuli should also lead to increased capacity for mental work.

As a child's power of control in imitation of finger movements increases we may expect increased mental power of such generalized type as is shown in 'concentration'.

These exercises should perhaps help especially at the ages of 6-8, when spontaneous movements are being rapidly replaced by movements controlled by external stimuli, i.e. by the occupational movements of the child of seven to ten.

The exercises will show the most obvious results with a child who, for one reason or another exhibits more spontaneous movements than are normal for its age. For example, the 'nervous' type of child, the 'over sensitive', the very 'imaginative', often have very good brains but their extra spontaneous movements (fidgety fingers, corrugating foreheads, twitching lips, shrugging shoulders, shuffling feet, etc.) indicate that some neurones are still wasting energy in response to self-originating stimuli in the infantile way. They need to be brought under control, and made ready to work in useful neuronic patterns in response to external stimuli, and this control is helped by these exercises.

Exercises cannot be given simultaneously to many children:

It is impossible to give these exercises to all children in a class of forty-five since they can only be used with individual children and cannot be given satisfactorily to even two at the same time, if real accuracy in imitation is the aim.

Need to select children by observation of their movements:

Children who have been observed to show extra movements, 'spreading area'—'poor eye-movements,' lack of co-ordination, who have been classed by their hand balance as 'Nervous' or 'Weak', will be found to benefit by a daily five to eight minutes course of these exercises for perhaps a month. Children too slow in response can also be helped. There are generally at least six children in an average class (age 6-8) who obviously need such exercises, for one reason or another.

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